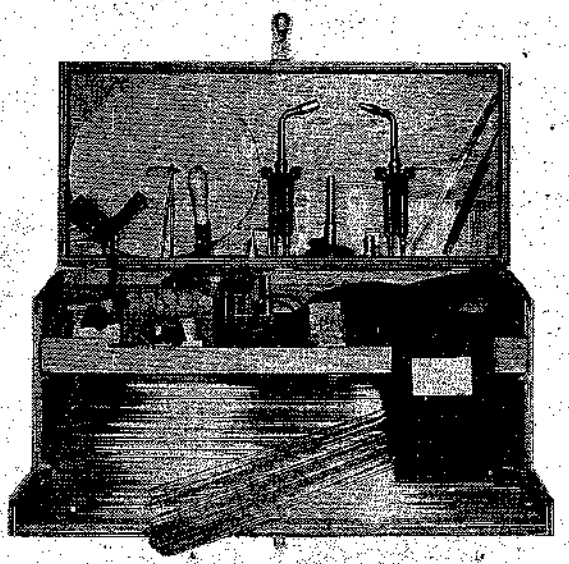
John E. Noel | Room 209 | Stock Room

OPERATION AND EXPERIMENT MANUAL



LABORATORY GLASS BLOWING COURSE

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ATOMIC LABORATORIES, INC., 3100 Crow Canyon Road, San Ramon, California

Subsidiary Cenco Instruments Corporation

LABORATORY GLASSBLOWING COURSE

by

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Instructor of Student Glassblowing

Berkeley, California

Copyright

by

Morley Corbett

1955

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INTRODUCTION

Glassblowing is one of the few handicrafts that have managed to flourish in the age of machines and mass production techniques. There are several reasons for this, the principal one being that no one has as yet been able to perfect a mechanical claw with the agility, dexterity and delicate control of the human hand. Until that time comes, we may expect glassblowing to remain one of America's most important and most remunerative professions.

Yet, in spite of all the attractions of glassblowing, the American educational system seems hardly aware of its existence. There are virtually no instruction books or manuals available to apprentice glassblowers, and high schools and colleges offering regular glassblowing courses are few and far between. Apparently the only way present-day Americans can learn the art of glassblowing is to get a job with a glassblower. This is the time-honored way of learning any trade, but not very much in keeping with the spirit of modern education. There is just as much reason -- if not more -- for high schools and colleges to offer a course in glassblowing as there is for them to offer courses in painting, carpentry, accounting, or in any of the other countless trades and professions.

The hourly wage of an American glassblower is well above the average for most trades. Furthermore, a high school or college can literally save hundreds of dollars a year by having a laboratory glassblowing class, since the students in this class, after just a few months' training, can themselves make the simple repairs on broken laboratory equipment that would otherwise have to be sent out and paid for at high professional rates. More important, after completing this course students can actually make many expensive items like condensers, cold traps, Dewar flasks, distillation flasks, and simple vacuum systems -- all at great savings to the school or college. In other words, a laboratory glassblowing course will actually more than pay for itself in just a few months.

To help speed the day when glassblowing will be given its deserved place in the high school and college curriculum, I have here set down in words and drawings a complete laboratory glassblowing course -- the same course I have been teaching students at the University of California for the last three years.

Morley Corbett

MATERIAL

The following materials are supplied in the Scientific Glassblower's Set manufactured by Atomic Laboratories, 3086 Claremont Ave., Berkeley, California. They may also be purchased piecemeal from any large laboratory supply house. The supplies and equipment included are basic to any professional glassblowing course and, while many items might be added, none should be removed. The list includes enough Pyrex glass to fill the requirements of a class of 5 - 10 students throughout the 21 hours of instruction that correspond to the 21 lessons. (See Figure #1, Lesson One, for illustration of most of the items listed.)

✓2 National Blowpipe Burners, No. 3A (1 with stand)

✓1 V Stand

✓1 Bunsen Burner

✓1 Brass Flaring Tool (wood handle)

✓1 Carbon Rod

✓1 Blow Hose (complete with swivel and pipe stem)

✓1 Tweezers

Files 1 Flat File

✓30 Feet of 1/4" x 3/32" Rubber Tubing

✓10 Rubber Policemen

✓1 Box of Corks

✓3 Rubber Stoppers (fitted with small glass tubing)

✓1 Dydimium Glasses

✓1 Roll Asbestos Tape

ok ? 18 lbs. Assorted Pyrex Tubing (3 mm. to 41 mm. dia.)

ok? 1/2 lb. Pyrex Glass Rod

✓3 1-ft. lengths .020 Tungsten Wire

✓4 1-ft. lengths 8 mm. Nonex Glass

✓1 Soapstone Pencil

REMARKS ABOUT EQUIPMENT

Burners

You are supplied with two National blowpipe burners, one of which will be used for glassworking, the other for annealing. The glassblowing burner comes with stand already attached, but the burners can also be identified by the differences in their tips, which are interchangeable. The glassworking burner is equipped with two pointed tips numbered Oxy 2 and Oxy 3. The annealing burner has two large round tips numbered N1 and N2.

V Stand

A metal cradle used to support one end of a long length of glass while the glass is being worked.

Bunsen Burner

For use as a pilot light and for pre-heating glass. Make it a standard rule to warm any piece of glass 1/2" or larger in your Bunsen Burner before putting it directly into the fire of your glassworking burner.

Flaring Tool

For flaring the ends of glass tubing and making a flat bottom from a rounded bottom or "test tube end." In the latter case it is used as a paddle and pressed against the softened end.

Carbon Rod

For flaring the ends of glass. It can more readily stand a direct oxygen fire than the flaring tool.

Blow Hose

This is to facilitate blowing into the tubes being worked. Note the swivel end, allowing you to blow into a piece of glassware while it is being rotated.

Tweezers

The main use of tweezers is for grasping and pulling off hot ends of glass, also for flattening or squeezing heated tubes tubes together.

File

For scratching glass preparatory to breaking it. Your file should be kept sharp by periodically grinding the two edges on an emery wheel.

Rubber Tubing

To connect burners to gas, air and oxygen outlets.

Rubber Policemen

To close one end of a piece of glass so you may blow into the tube from the other end. These are really rubber sleeves, one end fitting over the glass tubing, the other closed by a prefitted cork.

Box of Corks

Same purpose as above.

Rubber Stoppers (with glass tubing inserted)

For use when the diameter of the tubing being worked is too great to attach the blow hose directly. Instead it is attached to the smaller diameter tubing inserted in the rubber stoppers.

Dydimium Glasses

Never do any glassblowing without wearing them. They are made from special glass that cuts out injurious sodium light given off when glass is heated, allowing you to see your work very clearly when it is in the fire. They also protect your eyes from glass fragments.

Asbestos Tape

For centering one piece of glass tubing in another, such as when making a "cold trap" or condenser. (See Lesson 15)

Pyrex Glass

This type of glass is used almost exclusively today in the fabrication of scientific apparatus. It is highly resistant to chemicals, corrosive acids, and thermal shock. Some of the characteristics of this glass important for a glassblower to know are listed below:

Softening point	820° C.
Strain point	510° C.
Annealing point	560° C.
Linear coefficient of expansion	32×10^{-7} per ° C.

Only a very few substances attack Pyrex -- strong alkalies and hydrofluoric acid.

Tungsten Wire

For making electrodes and other electrical leads, for flaring small-diameter capillary tubing, for drilling holes in glass, etc.

Nonex Glass

Do not use your Nonex Glass for any other purpose than given in Lesson 20. This glass is made especially for sealing to tungsten wire and it has an expansion coefficient close to that of tungsten. This means that upon heating and cooling it expands and contracts very nearly the same as the tungsten wire that you are attempting to seal into it. Always keep your Nonex Glass separate from your Pyrex.

EQUIPMENT THAT MUST BE PURCHASED LOCALLY

In addition to those described above, the only other materials necessary for glassblowing are oxygen and compressed air, pressure regulators, and a natural gas outlet. Many schools and colleges already have some or all of these. High freight costs should be avoided by purchasing whatever you need locally.

Pyrex Glass can only be worked at relatively high temperatures. Only a combination of oxygen and natural gas (oven gas) will produce this heat safely. For annealing, a substantially lower heat is required and this is best obtained from a combination of natural gas and compressed air.

(Note: It is assumed that every home, school and college has natural gas. If not, this may also be procured in tanks from oxygen supply houses. Arrangements can easily be made with your local utilities company to put gas outlets in home workshops.)

The following list describes in more detail the various pieces of equipment that must be purchased locally:

Oxygen Cylinders

Oxygen tanks come in several sizes -- 120, 80, and 40 cubic feet. Since large amounts of oxygen can be consumed in glassblowing, it is less expensive to order the largest size tank. Tanks are rented, not sold, and may be procured by looking under "oxygen" in the yellow section of your telephone book. The Air Reduction Company, Linde and Stuart Oxygen Companies are the nation's largest suppliers. Tanks are initially rented for approximately $6.00 and refills cost the same. A one-hour glassblowing session with about 10 students will use up approximately 80 cubic feet of oxygen.

Oxygen Regulator

An oxygen regulator valve is always necessary since full oxygen tanks have 2000 pounds pressure. Proper pressure for glassblowing is from 8 to 12 pounds. *A simple single stage regulator with a pressure indicating gauge can be rented from any company supplying oxygen. Local welding companies will usually rent regulators for a few dollars monthly.

Compressed Air Cylinder 80 ft³

Everything said about the oxygen cylinder is equally applicable to the compressed air cylinder. It may be obtained from the same sources of supply, comes in the same sizes and costs approximately the same. If, as may be the case, your school, college or home workshop already has compressed air from a central location, all you need do is attach an air reduction valve (see below) to the air line. Then after the house pressure has been reduced to 8 to 12 pounds, attach to the rubber hose which connects to your glassworking burner.

Compressed Air Regulator Single stage pressure regulator with gauge

If you use compressed air from a cylinder, you will need a pressure regulator. If you already have a compressed air system you need only an air reduction valve, which can be purchased from your local oxygen supply company. Or you can rent one from a welding company for only a few dollars per month.

Having now learned to identify the materials supplied in the Scientific Glassblower's Set and having procured all the necessary equipment that must be provided locally, you are ready to begin Lesson 1.

Lesson 1

SETTING UP GLASSBLOWING BENCH AND LOCATING EQUIPMENT PROPERLY

Step 1

A table or bench on which to work is essential. The top should be approximately 48" x 30" and covered with a fire-resistant material such as Transite, Asbestos paper or Asbestos cloth. The height of the table may vary, depending on whether you prefer to sit or stand while working. Good lighting is absolutely necessary. When working glass, the lighting of the room should be such that no shadows fall upon the glass. Overhead fluorescent lighting is recommended if evenly illuminated at all angles. Thick or uneven areas are more easily discernible when all direct reflections are eliminated. The ideal location of the light source is from the side or back -- not in front of the glassblower.

Step 2

Place oxygen and compressed air cylinders on the floor at the extreme right of the bench and secure them firmly to the wall or table by means of a strap or chain clamp so they cannot fall or be knocked over. The natural gas outlet should be located in close proximity to the cylinders. If it can't be, then move the cylinders so that all hoses come from a central area. Hoses should always come underneath the bench.

Step 3

Take the glassblowing burner (the one with the small tip) and its stand and place it in a slot 1" wide by 12" long cut through the bench perpendicular to its long edge and 19" from the right-hand edge of the bench as you face the bench. The reason for the slot is to protect the hoses connected to the end of the burner and to firmly position the burner so it can be moved backward and forward. The slot also permits the burner to be lifted from the bench top.

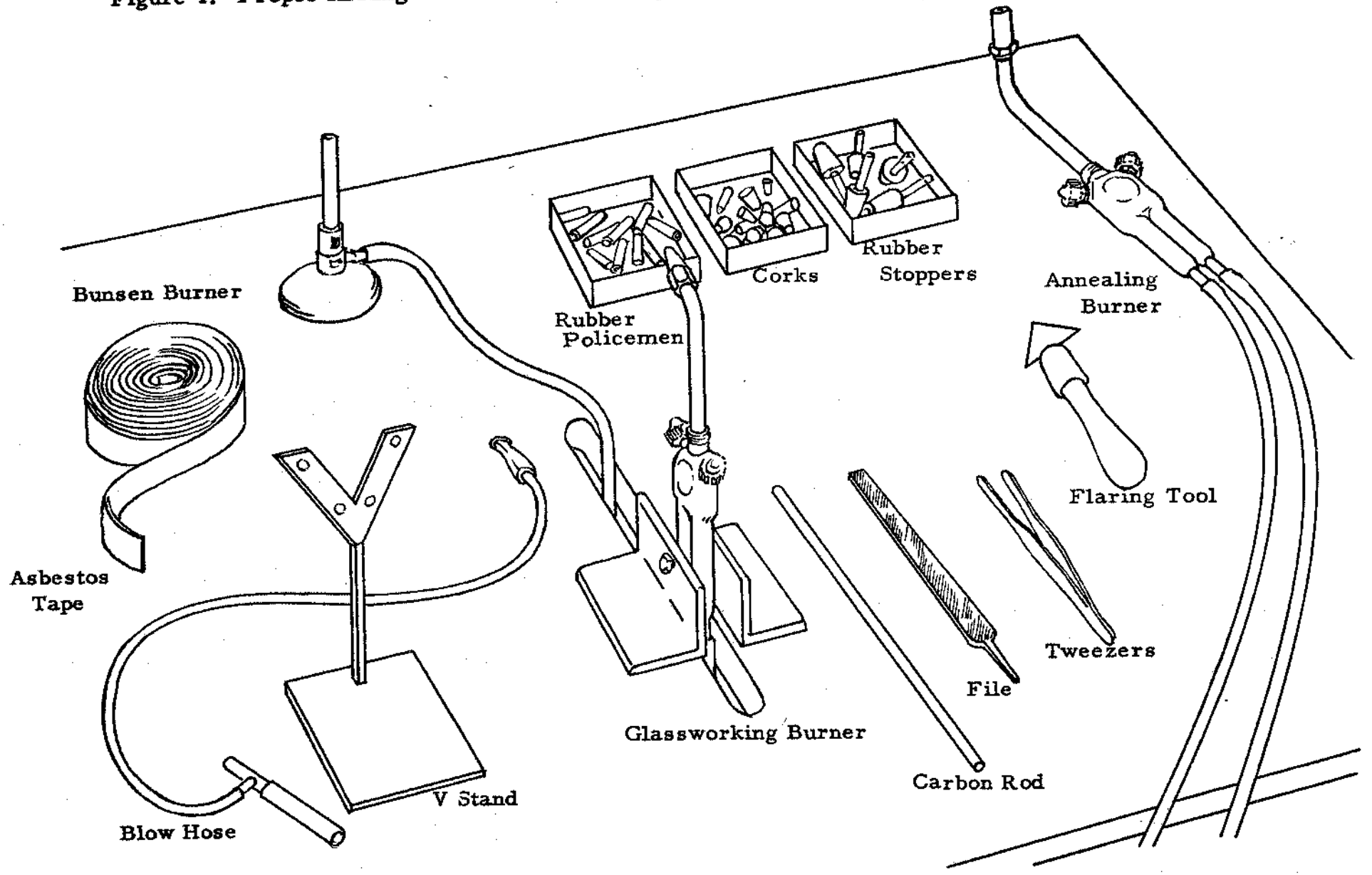
Step 4

The equipment listed below should be placed to the right of your glassworking burner within easy reach. (See Figure #1.)

Annealing burner (one with large tip). Place at extreme right near end of bench.

Flaring Tool.

Figure 1. Proper Arrangement of Glassblowing Bench.



Carbon Rod.

Tweezers.

File.

Corks, rubber policemen and rubber stoppers fitted with glass tubing should be placed to the right rear of your bench.

Step 5

The equipment listed below should be placed to the left of your glassworking burner and within easy reach. (See Figure 1.)

V stand support.

Bunsen burner (to the rear).

Blow hose.

Roll of asbestos tape.

The 18 pounds of assorted Pyrex Glass may be kept in your chest under the bench unless there is a rack available. Tungsten wire and Nonex glass should be kept separately either in a rack or in your chest.

Dydimium glasses, when not in use, should be put back in their box. This is to prevent scratching the lenses. They can be placed at the rear of your bench or in a drawer if you have one.

Lesson 2

HOW TO SET UP AND OPERATE BURNERS

Attaching Hose

Cut two suitable lengths of 1/4" by 3/32" rubber tubing and place one end of each on the two valve ends of your glassworking burner. The valves on your burner are identified as Red for gas, Green for oxygen. The gas hose is attached to the natural gas outlet, the oxygen hose to the regulator valve of your oxygen tank.

Cut two more pieces of rubber tubing and attach to your annealing burner. The valves on this burner are identified as Red for gas and Green for air. The gas hose is again attached to the natural gas outlet in your room, the air hose to your air compressor or to the reduction regulator on your compressed air cylinder.

Cut one more piece of rubber tubing and attach to Bunsen Burner with the other end going to the natural gas outlet.

Glassworking Burner

Your glassworking burner has two tips, Oxygen 2 and Oxygen 3. Looking closely, you will see that the Oxygen 3 has a larger hole in it. These two different size tips allow you to make an extremely small flame or a larger fire.

Whichever tip is used, the proper method for turning the burner on and off is as follows:

Turn the gas valve counterclockwise and light the burner. Adjust flame to about 5" long. Next, turn your oxygen valve slowly clockwise. Now that you have introduced oxygen into your gas flame, you regulate your burner to give you the flame you desire. As a general rule, use Tip No. 2 for working any glass up to 10 mm. in diameter -- No. 3 for up to 41 mm. in diameter.

When turning burner off, regardless of what size flame you are using at the time, always increase your gas before decreasing your oxygen. Otherwise, you may do serious damage to the burner. Instead of blowing itself out, the flame may move back into the burner and hose. This must be avoided at all costs.

If you experiment with Tip No. 3 you will notice that after introducing oxygen into the gas flame when it is about 5" long, you will have a fire that is

about 1/2" in diameter and 6" long. Note that by increasing or decreasing the gas alone you can have a wide variety of flame sizes. The same holds true with Tip No. 2, only on a smaller scale.

Annealing Burner

The annealing burner is equipped with two different size tips. They are identified as N2 and N1. Using the N2 tip, turn your gas valve on and again burn a flame about 5" long. Now turn your air valve on. You will notice that unlike your Glassworking Burner it produces a large bushy flame. This type of flame is used for annealing.

Annealing is the process which relieves thermal strains that are always set up in a piece of Pyrex glass when heated above the strain point, 510° C.

It is obvious that when working a piece of glass in your oxygen fire it will be heated at various places to a much greater temperature than 510° C. These harmful strains must be relieved by annealing -- by reheating the entire area that has been previously worked in the oxygen fire with a large bushy gas air fire.

The piece should be heated until the first tinge of red appears over the entire affected area. Then cool by slowly decreasing the air until you are holding your work in nothing but a gas flame. It is not necessary to hold it in the gas flame until it is black with soot. Lay your work down at the point when soot first begins to form. Don't let the area you've been working touch any cold surface.

Bunsen Burner

The Bunsen Burner is used as a pre-heater. The temperature may be increased or decreased by turning the air intake adjustment at the bottom. The Bunsen Burner will be found useful for pre-heating larger pieces of glass, which if placed directly in the fire might break or crack. Pre-heated ware may be placed directly into your glassworking fire. It also permits speedier work, as one piece can be warmed while another is being worked.

Lesson 3

CLEANING AND CUTTING GLASS

Preparation of Glass

Many difficulties encountered in glassblowing arise from using dirty glass. Dust or foreign material may burn into the glass rapidly when heated. Even fingerprints will burn into glass and never come out. Glass must never be worked unless it is perfectly clean.

One good method of cleaning is to wash glass thoroughly in hot water, using some kind of a water softener. Rinse in clear water and dry well. Solvents may be used but there is the ever-present hazard of heavy traces of vapors which may cause explosions and fire. A glassblower should keep his hands clean while working, as finger marks rapidly burn into glass and, once there, are not easily removed.

Cutting Glass

The following method of cutting glass tubing is useful for diameters up to 25 mm. (1 inch). Make a good deep scratch with the file on the outside of the tubing at the spot where the break is to occur. In making the scratch use considerable pressure. (See Figure #2.)

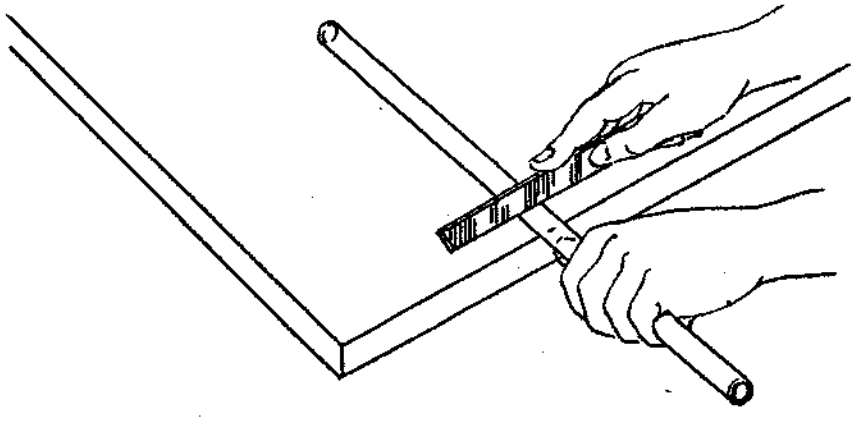


Figure 2

A method for cutting larger tubing is with a hot wire--that is, a resistance wire such as Chromel (about 22 gauge) connected through a Variac or slide wire rheostat. The wire is wrapped once around the tubing at the point of desired cut. The current is then increased until the wire is red hot. Then the current is turned completely off and the heated arc of the glass doused with water, which can either be poured from a small container or dabbed on with a wet piece of cotton.

Make the scratch with one stroke which is perpendicular to the axis of the tube. Do not try to saw the tube, as this tends to widen the scratch. A wide scratch does not break as easily as a thin one.

Having scratched the tube, wet the scratch. Wetting the scratch further weakens the glass at the scratch. Next, grasp the tube firmly so the scratch is between the knuckles of the two index fingers and opposite the thumbs. Bend the tubing at the scratch creating tension on the scratched side, and at the same time tend to pull the tube apart. Imagine that you are breaking a stick that has been sawed part way through. Glass is strong and a good amount of force will be needed. If you have confidence that the break will occur cleanly at the scratch you will not be afraid to use the required amount of force. (See Figure #3.)

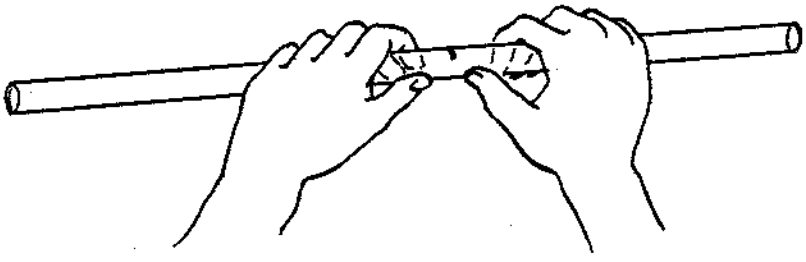
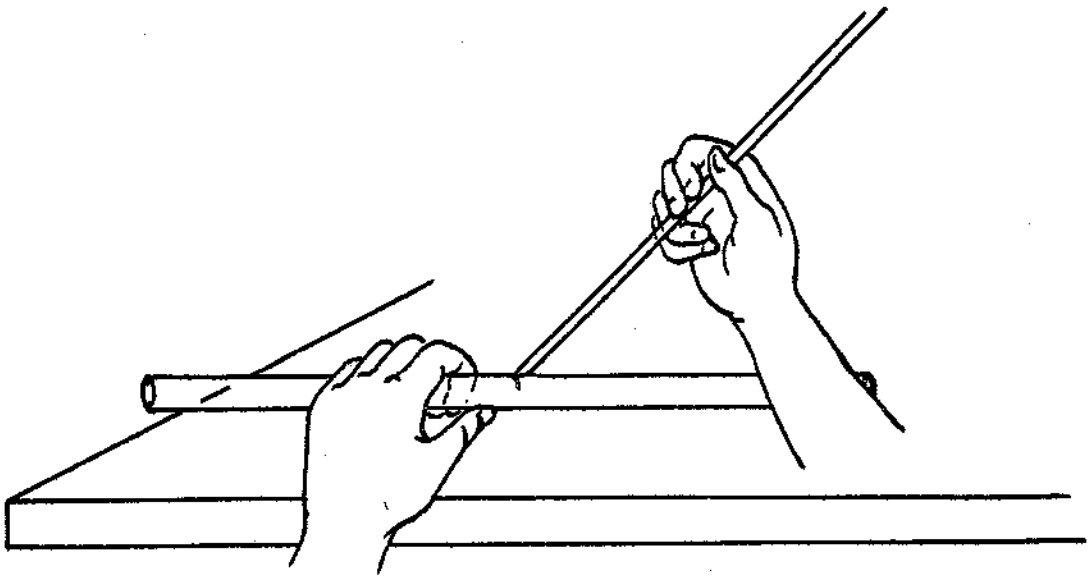


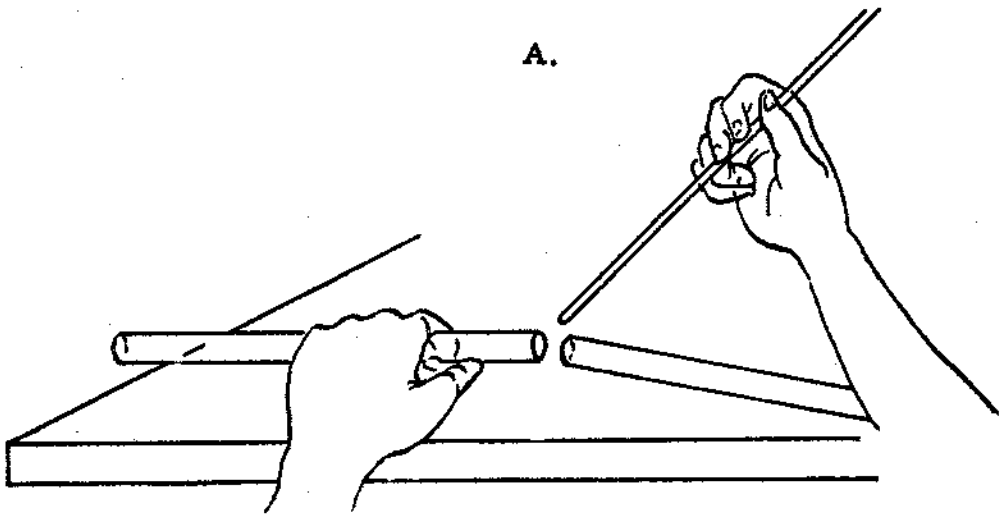
Figure 3

Another method of breaking glass is by applying a hot rod to the scratched tube. This is done in the following manner:

Make a deep scratch on the tube as described above. Hold this tube in one hand and with the other take a piece of 4 mm. rod and soften the end in the glassblowing burner in the slot. When the end of the rod is molten, touch it to the scratch. If the scratch is straight the tube will break cleanly. Keep tube close to bench top so when it falls it won't break. This method, while not as efficient as the first, is convenient to use in the case where assembled apparatus prevents grasping the tube in both hands. (See Figure #4.)



A.



B.

Figure 4

Lesson 4

PROPER PROCEDURE FOR HOLDING AND ROTATING TUBING

Uniform rotation of glass during heating and blowing is essential for obtaining an evenly distributed wall thickness. The process of rotating cannot be overemphasized; if you stop rotating while your work is in the flame it will sag or thicken on one side. Also, the slightest amount of blowing will blow a hole out of the side that is overheated. Only by continuous rotating can you get even, smooth work. You may rotate in either direction, but it is most common to have the top of the glass move away from the glassblower.

Tubing should be supported by the last three fingers of the left hand, which act as a bearing. The thumb and forefinger are then used to rotate the glass. The right hand supports the other end of the tubing. Here again, the thumb and forefinger are used to rotate the tube while the other fingers are used mainly for support. The palm of the left hand is downward, while that of the right is upward. This permits the glassblower freedom of movement in making U-bends and right-angle bends. (See Figure #5.)

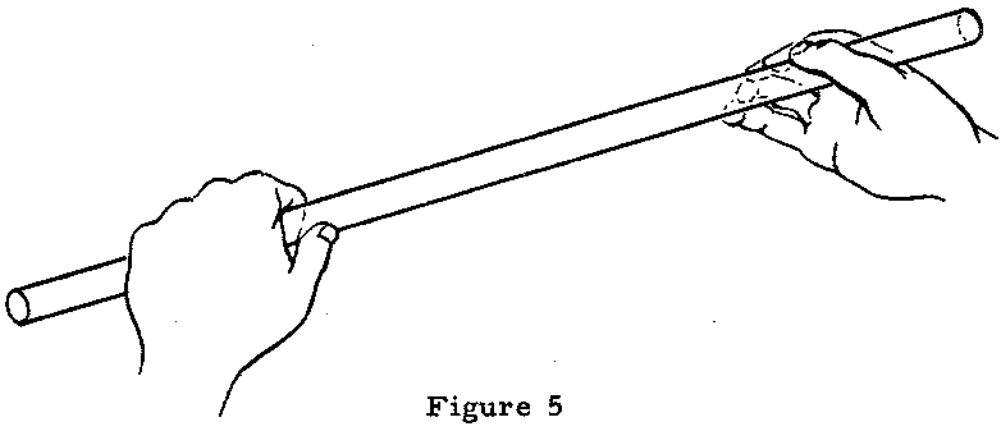


Figure 5

The important factors in rotating and holding tubing are:

1. Synchronize right and left hand movements so as to prevent twisting of the tubing. This may be practiced by joining two pairs of tubing by a piece of cloth and then practicing rotating without twisting the cloth. (See Figure #6, A & B.) Another way is to mark with your soapstone pencil the end of two pieces of tubing and then try to keep the marks parallel while turning.

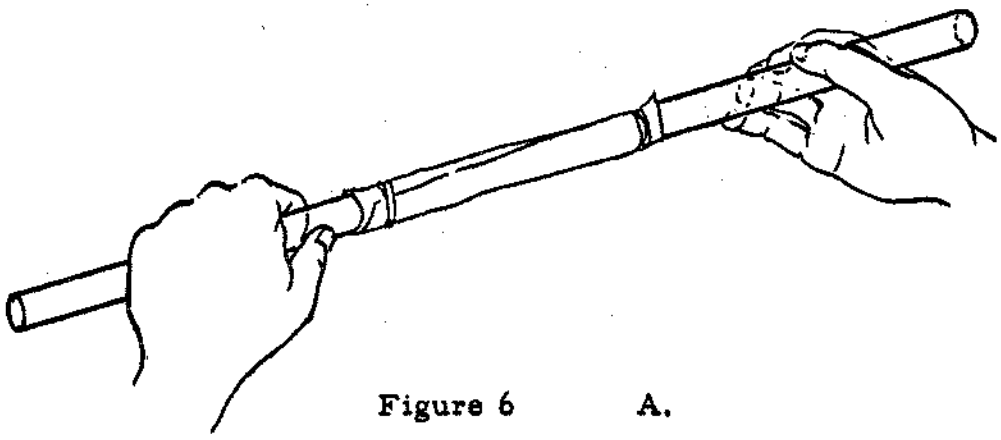


Figure 6 A.

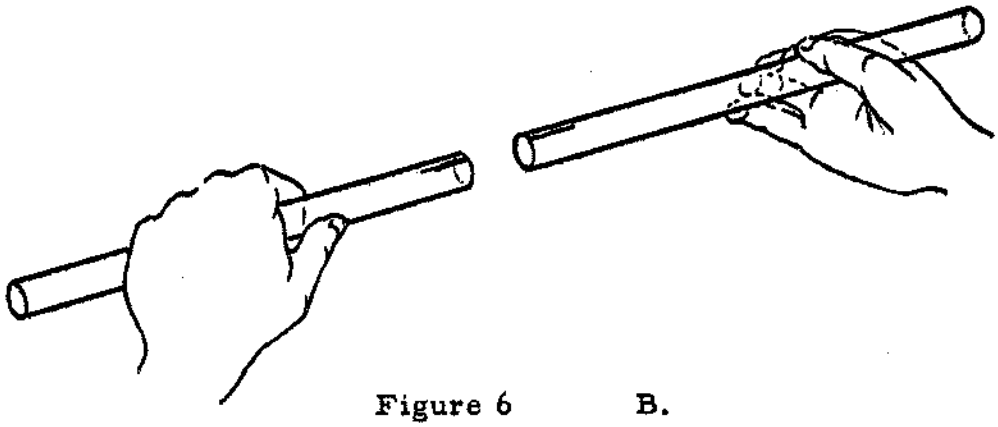


Figure 6 B.

2. Hold the tube in a straight line and do not bend at the heated zone.

3. Do not push or pull the tube unless it is necessary to constrict or change the wall thickness.

4. Don't try to hold a long or heavy piece of tubing in the left hand, but use your V-stand to support the end. In this case use left hand to turn tube, but not to support its weight. (See Figure #7.)

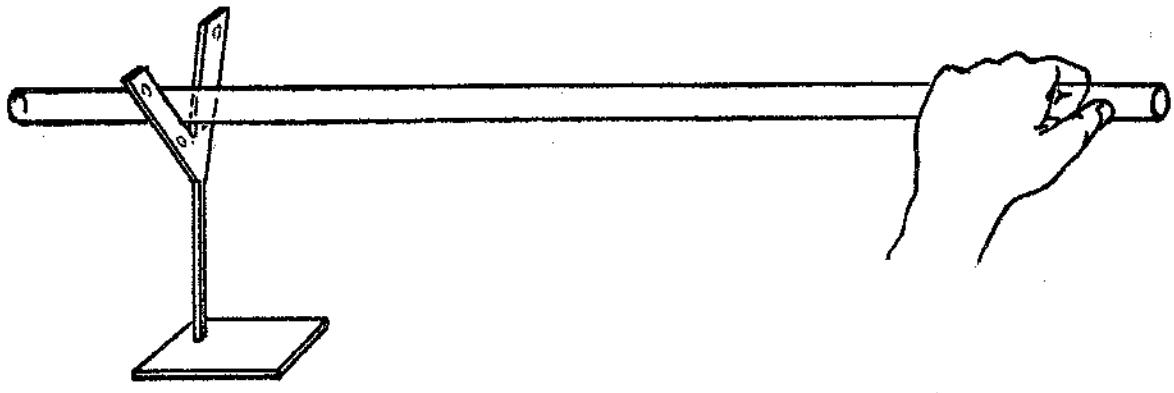


Figure 7

Remarks: Rotation is the means by which a glassblower keeps glass uniformly heated. If the glass were not uniformly heated, gravity would cause the hotter areas to sag out of shape.

Lesson 5

HOW TO MAKE TEST TUBES, VIALS, ROUND BOTTOMS AND TUBING SEAL OFFS

To make a round bottom, or test tube bottom, take a piece of 10 mm. tubing about 12" long. Attach the blow hose to one end and rest the glass tubing on the V-stand, so that your left hand is holding the tubing with the palm downward between the fire and V-support. (See Figure #7A.)

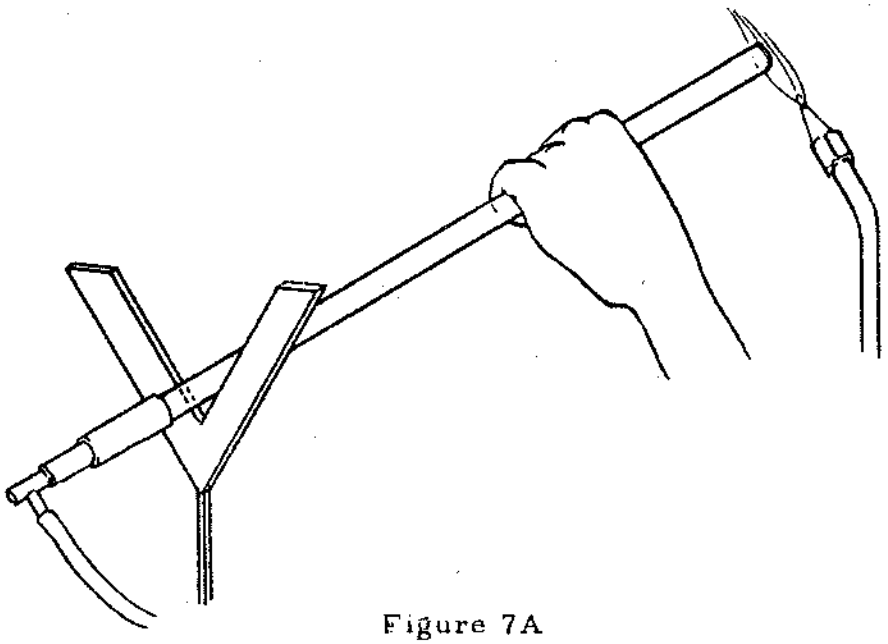


Figure 7A

Rotate the tube in the fire until the end is quite soft. Lift it out of the flame momentarily and grasp the softened area with your tweezers and pull the soft glass about 10 to 12 inches. Drop it back in the flame and allow it to part, and the closed end will reseal and get thicker. There will be a small bead left at the end of the tube. Rotate and blow gently until the end becomes hemispherical in shape and the bead disappears. (See Figure #8.)

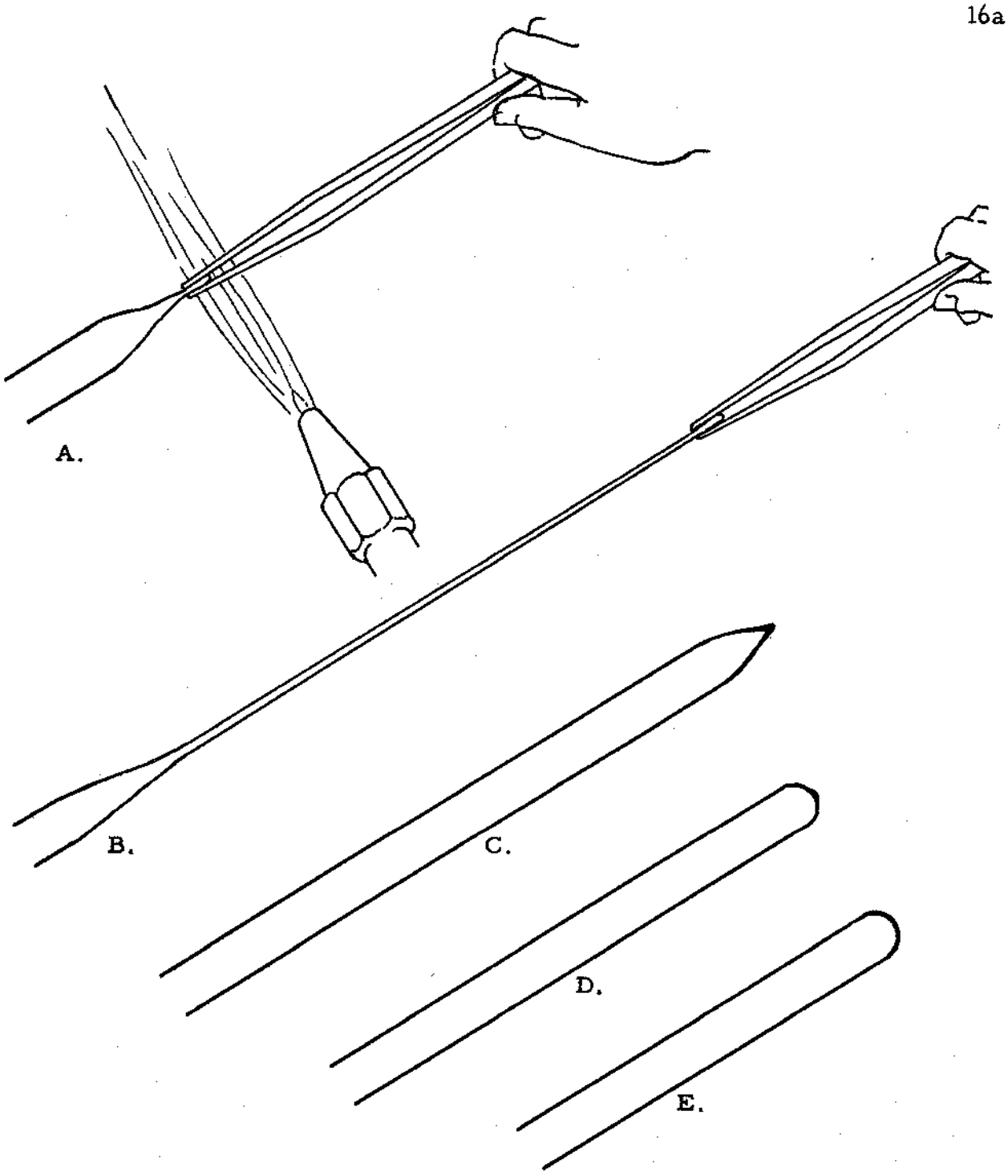


Figure 8

On small size tubing it may seem that the easiest way to make a round bottom is to heat the end through so that it collapses by itself and then blow the thick portion out into a spherical shape. However, you will note that unless your glass is extremely clean you will have a fine line extending through the rounded bottom of the tube. This will usually leak if you use this piece in a vacuum system.

Standard test tubes are so inexpensive it is cheaper to buy than to make them. But you will always need at least a few test tubes of odd sizes and diameters. Small vials, which are in constant demand by laboratories, are nothing more than test tubes with small diameters. Glass tubing provided in your Glass-blower's Set enables you to make test tubes and vials with diameters ranging from 3 mm. to 41 mm. in diameter.

Lesson 6

STRAIGHT OR BUTT SEAL

Joining two pieces of straight tubing together is the most common seal in glassblowing, and unfortunately one of the most difficult. Practice this seal until you can do it rapidly and smoothly with glass tubing of all diameters. Needless to say, it will be quite some time before you become proficient, but once you do you will have made a major step forward.

Choose a piece of 8 mm. tubing. Cut it into two lengths -- one about 15" long, the other about 8" long. On the longer of the two pieces fix your blow hose and swivel to one end and on the shorter of the two put a rubber policeman on one end. Next, turn your glassworking burner on so that you have a medium fire. The blue cone should be about 1/4" long. (Refer to Lesson 21 and see Figure #9.)

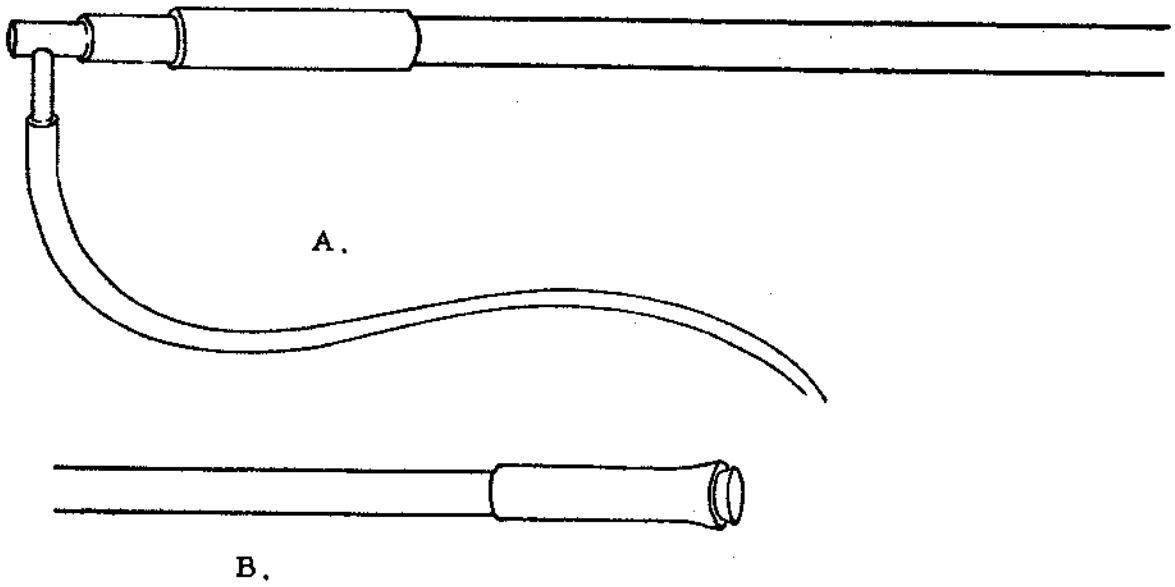


Figure 9

Heat by rotating in the flame until the ends of the tubes to be sealed together are softened. The tubes are then pushed together, and as soon as the glasses touch pull the tubes slightly apart so that the initial seal is not too thick. (See Figure #10.)

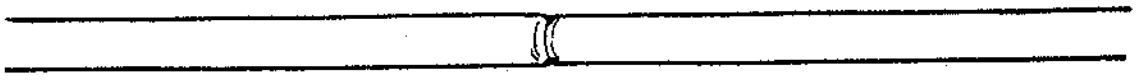


Figure 10

All of this is done without removing work from flame. The tubes should be brought together carefully and on the same axis, establishing contact at all points. If you were to take the joined tubes out of the fire at this time and inspect them, you would notice that the glass looked uneven and wrinkled at the area of contact. For this reason the tubes must be held together and rotated until the wrinkles are gone, without pulling or pushing.

Now continue rotating in the flame until the diameter is decreased and the wall thickness increased. No blowing up to this time is required. (See Figure #11.)

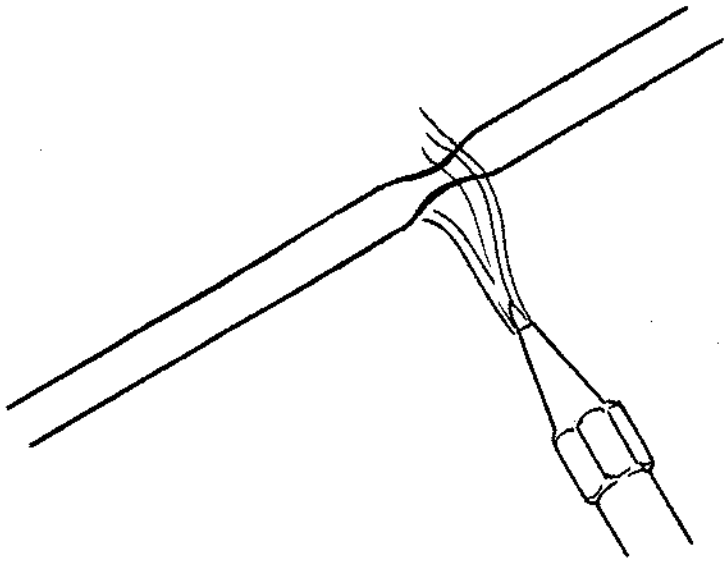


Figure 11

Always rotating, remove the tube from the flame and blow until the heated portion is slightly larger in diameter than the rest of the tube. (See Figure #12.)

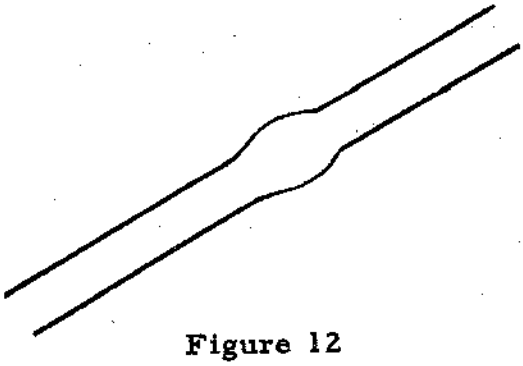


Figure 12

Still rotating and before the glass has a chance to cool appreciably, pull sufficiently to reduce diameter to correct size. (See Figure #13.)

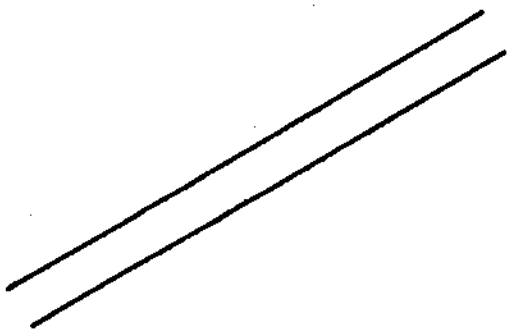


Figure 13

Be sure to practice making butt seals until you can make them perfectly every time. As you progress in glassblowing, you'll find that nearly every job you do involves sealing two tubes together in a straight line. As your work becomes more intricate, all seals must be made correctly the first time or you may have to begin an entire piece of apparatus all over again. One bad butt seal can result in hours of wasted time.

Lesson 7

STRAIGHT OR BUTT SEALS -- DISSIMILAR SIZES

Now that you have been shown how to join two pieces of tubing of the same size together, the next step is to learn how to join together tubing of different diameters.

To begin choose from your set a piece of 18 mm. tubing about 12" long and a piece of 8 mm. tubing about 8" long. Fasten your blow hose to the 18 mm. piece and cap one end of the 8 mm. piece with a rubber policeman or small cork. Take the 18 mm. piece in the left hand and rotate in flame until the end is so soft it almost, but not quite, collapses. Then grasp it with your tweezers and slowly pull away. (See Figure #14.)

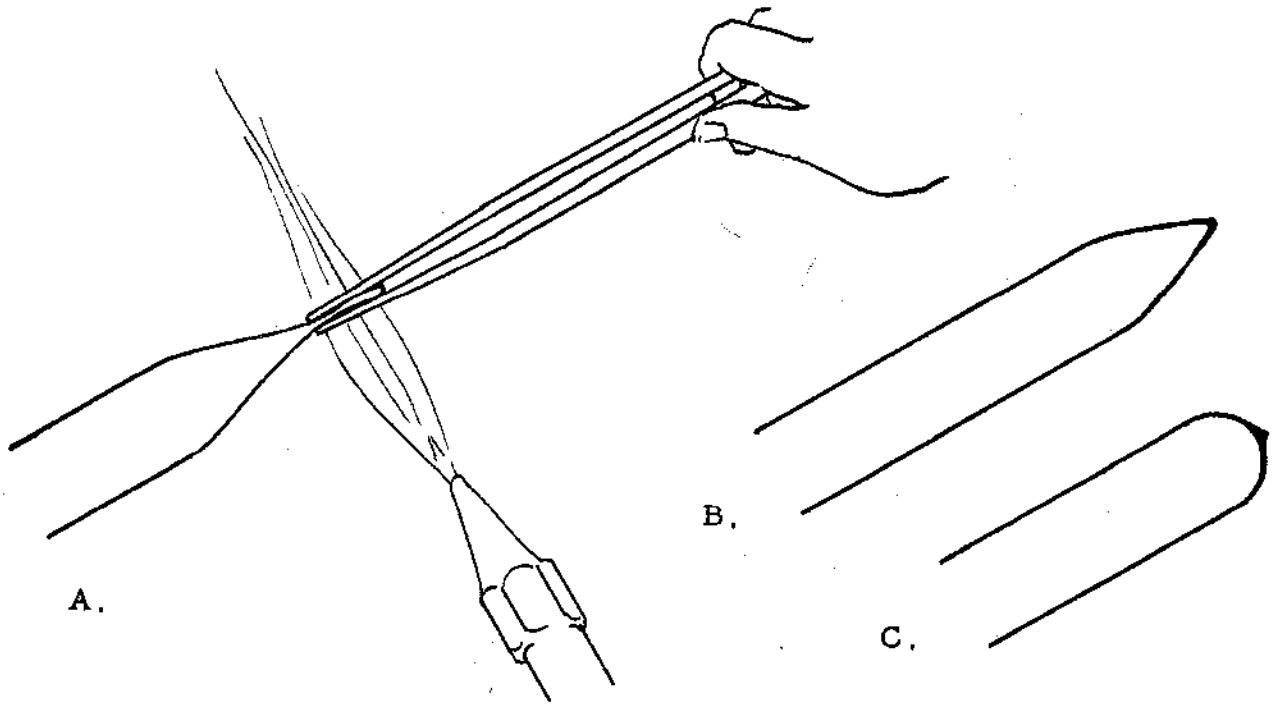


Figure 14

Continue to rotate the tubing in the left hand and allow the flame to pinch the tubing off. The closed bottom of the tube is heated uniformly so as to allow an even distribution of glass at the tip where the tube was pulled apart. A heavy drop or globule will remain and should be perfectly centered.

If your piece of glass looks like (B), turn your flame so it strikes the elongated shoulder, heat uniformly and blow. You should now have something that looks like (C). Allow this to cool a moment, then adjust your flame to a sharp fire and point it right at the heavy end, not on the shoulder,

but right on the heavy end. When it is soft enough to work, blow a small bulb out the end. Be sure it is no larger in diameter than the 8 mm. tube you are going to seal to it. You should now have something that looks like this. (See Figure #15.)

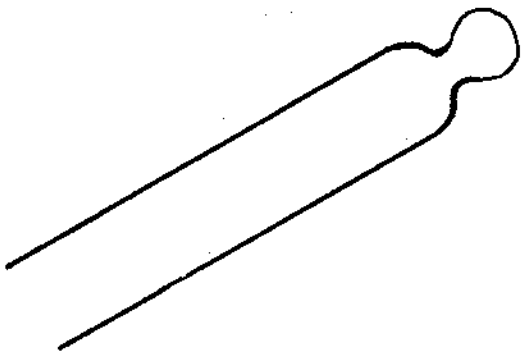


Figure 15

Now heat the extreme end and blow it away. The remaining tubulation should be 8 mm. outer diameter and about 1/8" long. Now you are ready to seal on your other tube. The rest of the operation is just a straight seal between two 8 mm. tubes as in Lesson 6. One thing to remember when joining the small tube is to keep your flame right on the seal or slightly to the right of the seal. Do not point the flame on the shoulder of the 18 mm. tube. (See Figure #16.)

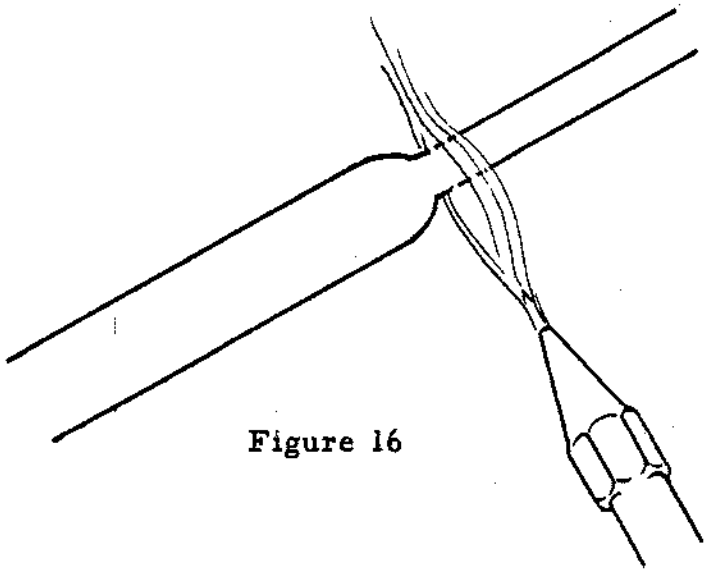


Figure 16

When this seal is finished it should look as in Figure #17. It should not be tapered, which will happen if your flame softens the large tube and rounded shoulder.

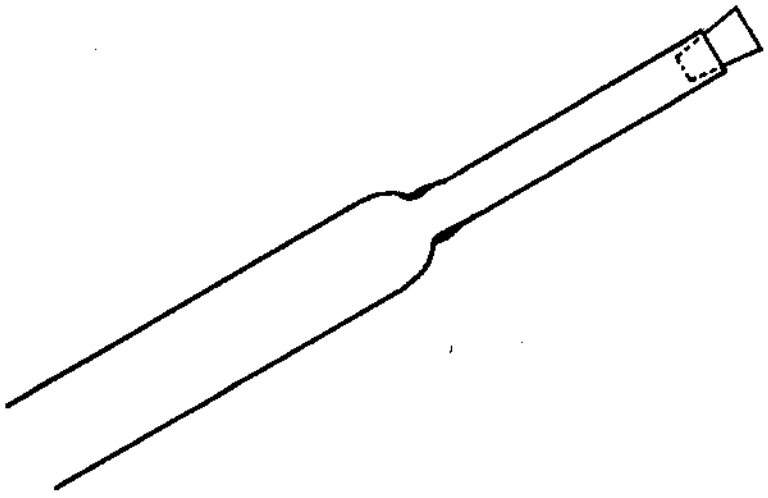


Figure 17

When, however, you become proficient in rotating, you should not stop here. After you have joined the two tubes together, blow and work the seal up into the shoulder of the larger of the two tubes. This makes a very nice-looking seal and if done properly the actual seal cannot be seen at all. (See Figure #18.)

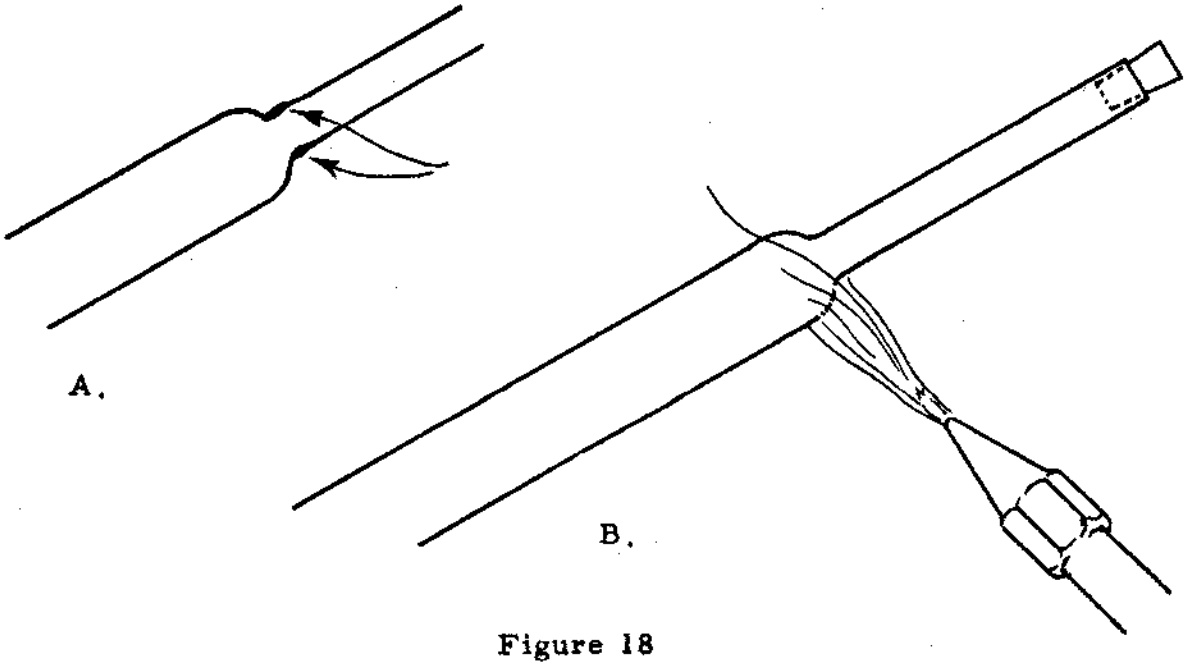


Figure 18

Lesson 8

T-SEAL

A "T" seal is essentially a straight seal, differing only in that it is not easily rotated except by use of a holder.

To make a "T" seal without rotating, take a piece of 12 mm. tubing about 8" long, put blow hose on one end and stopper the other end with a small cork. Now take a piece of 8 mm. tubing about 4" long and stopper one end. On the larger of the two tubes heat a spot on the surface by holding glass so that the top edge of the tube is just under the flame. Use a small, sharp fire. (See Figure #19.)

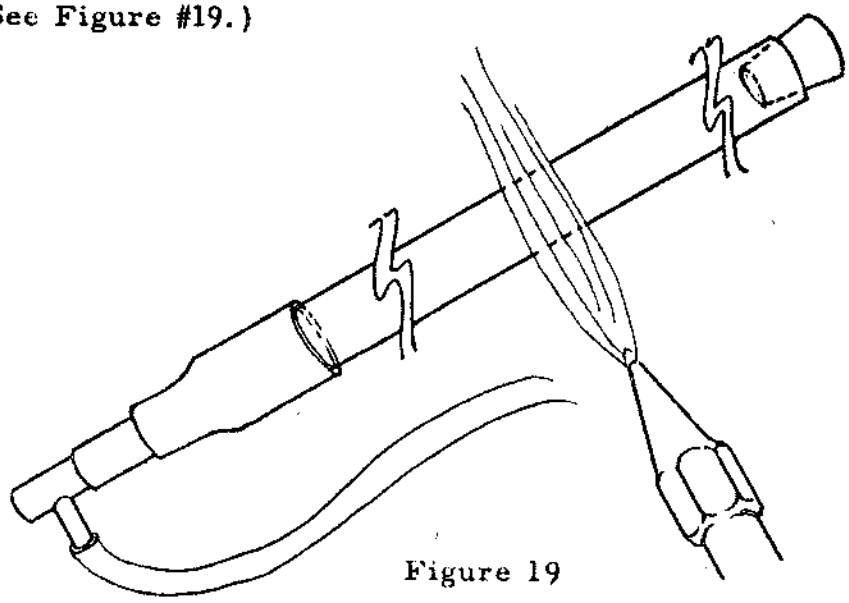


Figure 19

After heating, gently blow a bulge that is slightly smaller in diameter than the tube which is to be sealed on. (See Figure #20.)

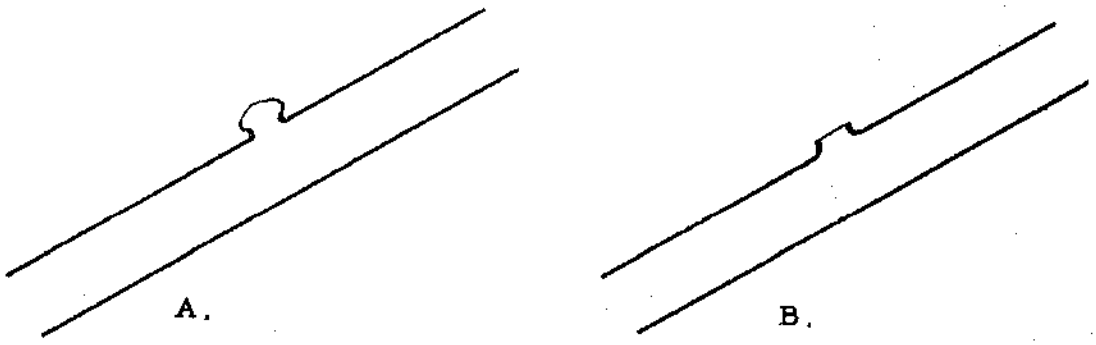
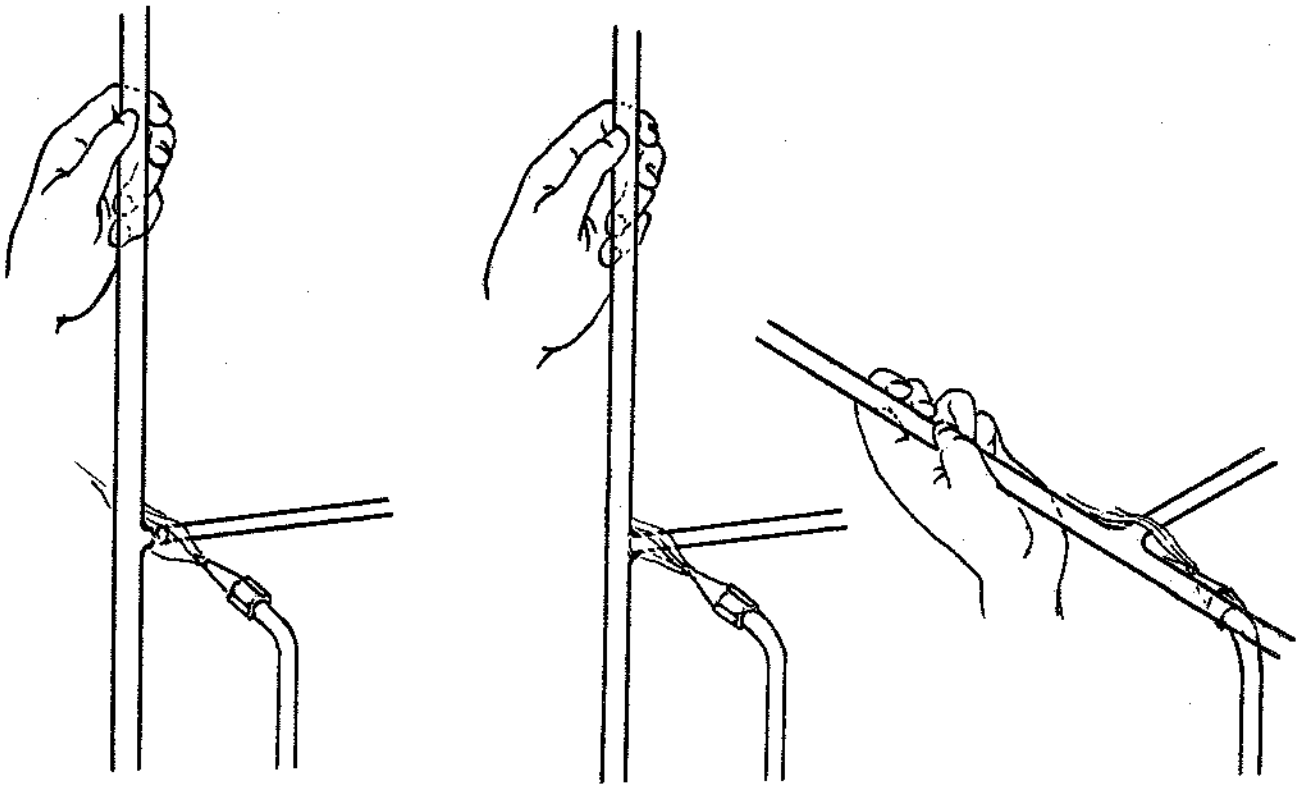


Figure 20

Reheat the top of this bulge and blow it away as in (B). Remember the size of the hole is controlled in the main by the size of the area heated before blowing.

Now hold this tube in the left hand between thumb and just three fingers so that the hole is to the left of the flame. Take your other piece of tubing in the right hand and heat it uniformly until the end is soft and just before joining the two, heat the other opening uniformly. (See Figure #21.)



A. B. C.

Figure 21

Lift out of the fire and press the two together quickly, pulling slightly as soon as complete contact has been made and blow slightly to expand heated area. If both edges are soft enough they will flow together upon contact and the small amount of blowing and pulling will give you a nice smooth seal as in (B). If, however, you find your seal heavy and uneven in wall thickness, heat one side at a time and blow gently only after the glass is sufficiently soft enough to work out the uneven area.

If you can make yourself a clamp which attaches to both ends of the tubing, leaving an area in the middle for the hole, you can then rotate the entire "T" as in Figure #22. The operation will then become fundamentally the same as making a straight seal.

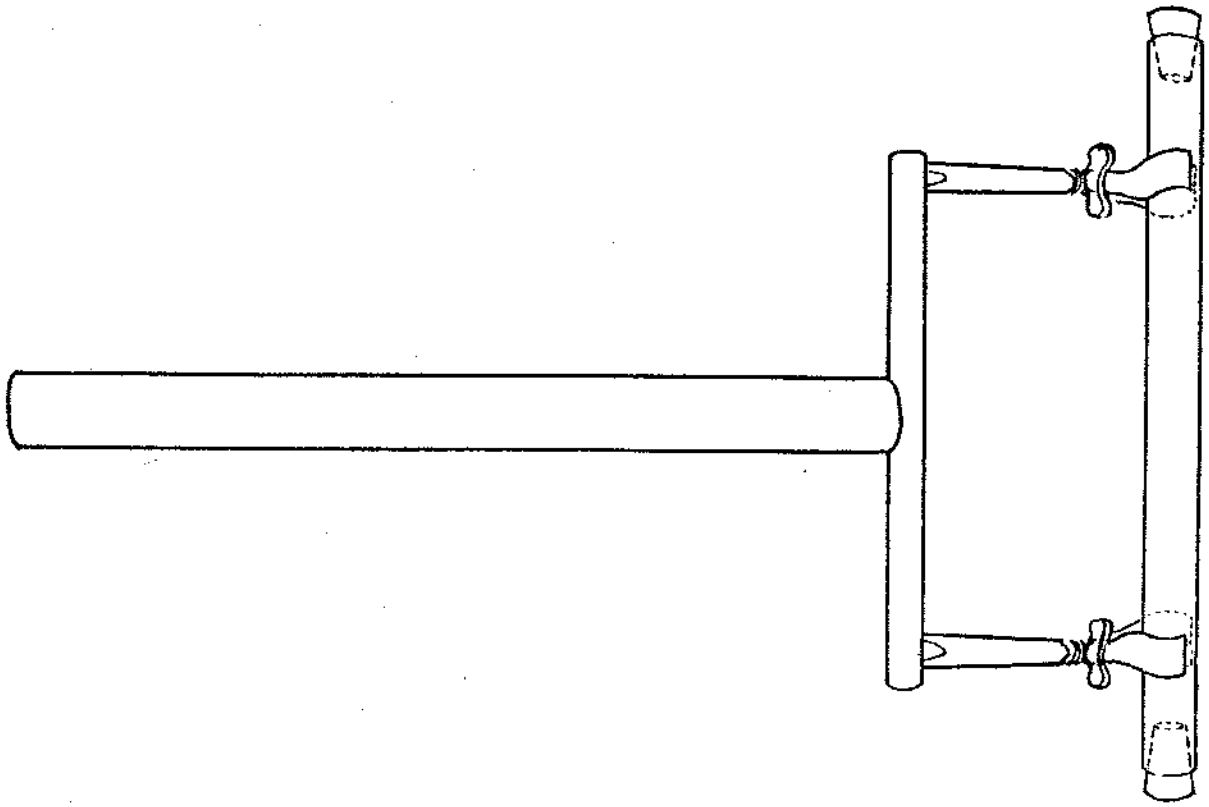


Figure 22

Later on when you learn how to make condensers, cold traps or any water-jacketed apparatus, you will find that a number of T-seals are necessary in their construction.

T-seals are mainly used to introduce two liquids or gases into one line. They are also used as simple distillation tubes with side arms.

Lesson 9

HOW TO MAKE FLAT-BOTTOMED TUBES
PROPER USE OF FLARING TOOL

Select a piece of 15 mm. tubing about 8" long and fasten your blow hose to one end. This piece of tubing should be long enough so one end will rest in your V stand support. Your left hand, which holds the glass, should be between the stand and the fire. (See Figure #23.)

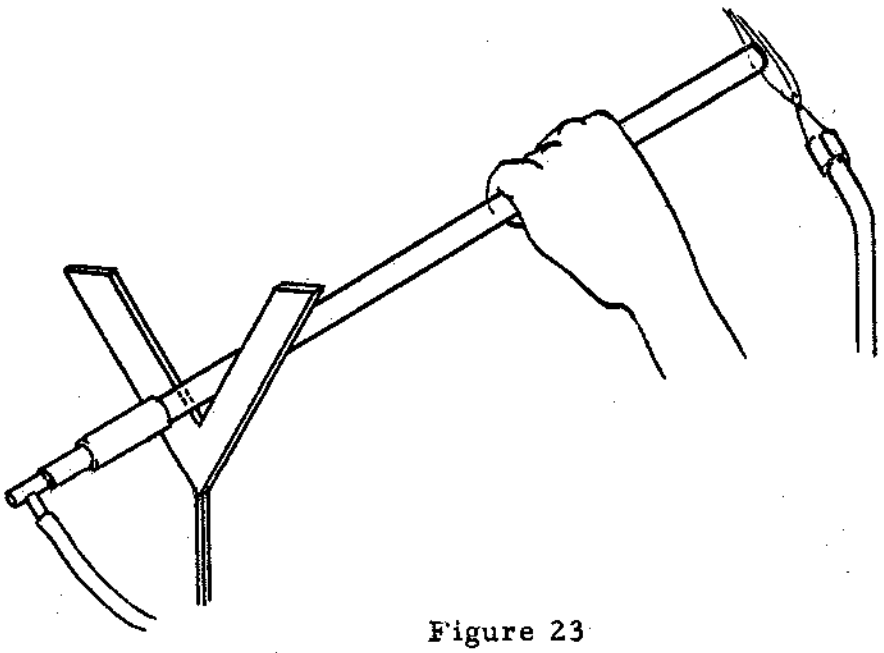


Figure 23

Rotate the tube in the fire until the end is quite soft by following the method outlined in Lesson 5. Then lift it out of the flame momentarily and grasping the softened end with your tweezers pull the soft glass out about 10 to 12". Drop it back in the flame and allow it to part, as in Figure #24.

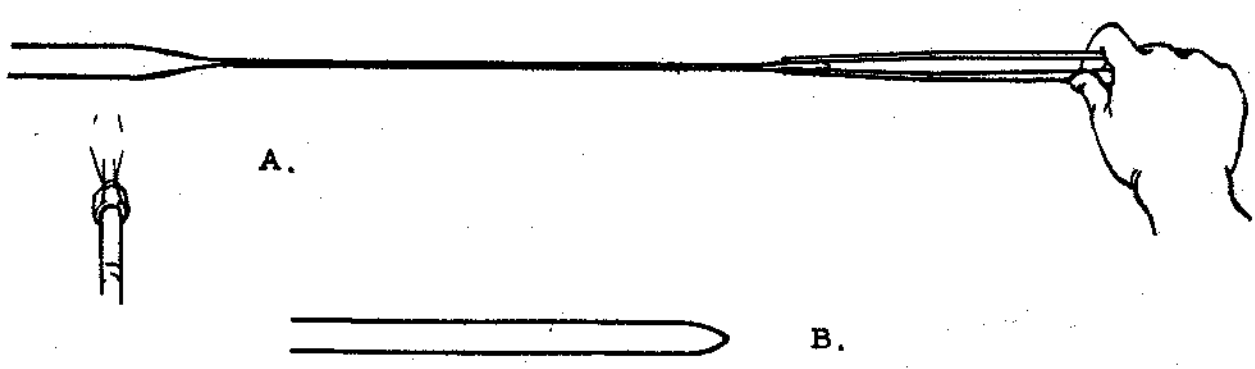


Figure 24

The closed end will now grow thicker. At this point, instead of blowing into the tube continue to rotate it in the fire and allow the end to become thickened and somewhat flat. (See Figure #25.)

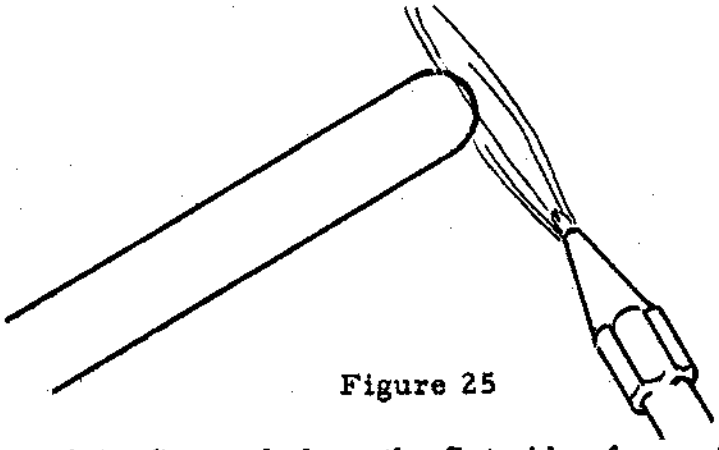


Figure 25

Now lift it out of the fire and place the flat side of your flaring tool against the soft glass and blow gently, all the while constantly rotating. (See Figure #26.)

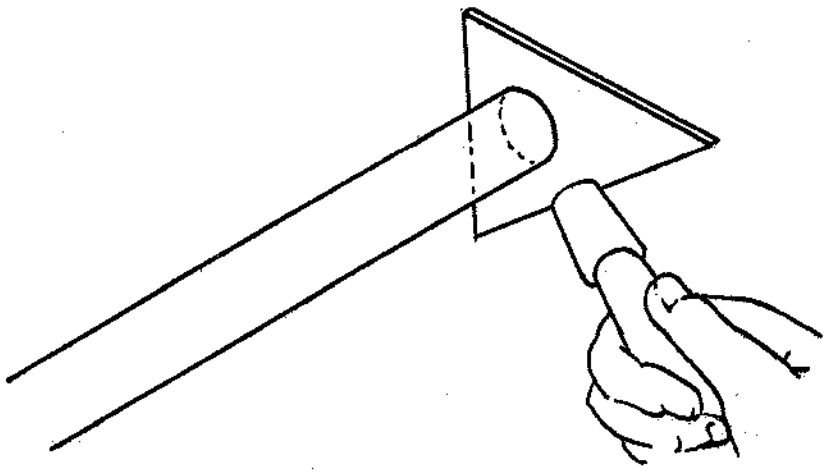


Figure 26

If a flat bottom is not produced, either the glass was not soft enough to conform to the flat paddle or your blowing was too powerful. In either case drop it back in the fire and reheat. If in the reheating process the glass becomes too thick pull it away with your tweezers and start all over. A proficient glassblower must be able to put flat bottoms on any size of tubing. The main thing to look out for is to keep a uniform wall thickness while making the bottom. An uneven bottom may be subject to thermal stress and strain, resulting in cracks or complete breakage.

Small boiling flasks, biology culture dishes and small-diameter drying dishes are just a few of the many kinds of apparatus that have flat bottoms.

Lesson 10

HOW TO MAKE U BENDS FOR SIPHON TUBES

By now you should have fairly good coordination between your hands. Good coordination is essential to make a proper U bend. The diameter of the tubing and the distance between the bend will determine the length of tube to be heated.

Choose a 12" length of 8 mm. tubing, stopper one end and put your blow hose on the other. Rotate in the flame. Heat an area in the center of the tube about 1-1/2" long until it is soft and slightly decreased in diameter, as in Figure #27. (Right now you will find out whether you have practiced your rotating enough. If not, you should stop and go back to Lesson 6 and seal two tubes together again for the practice of coordinating properly between your hands.)

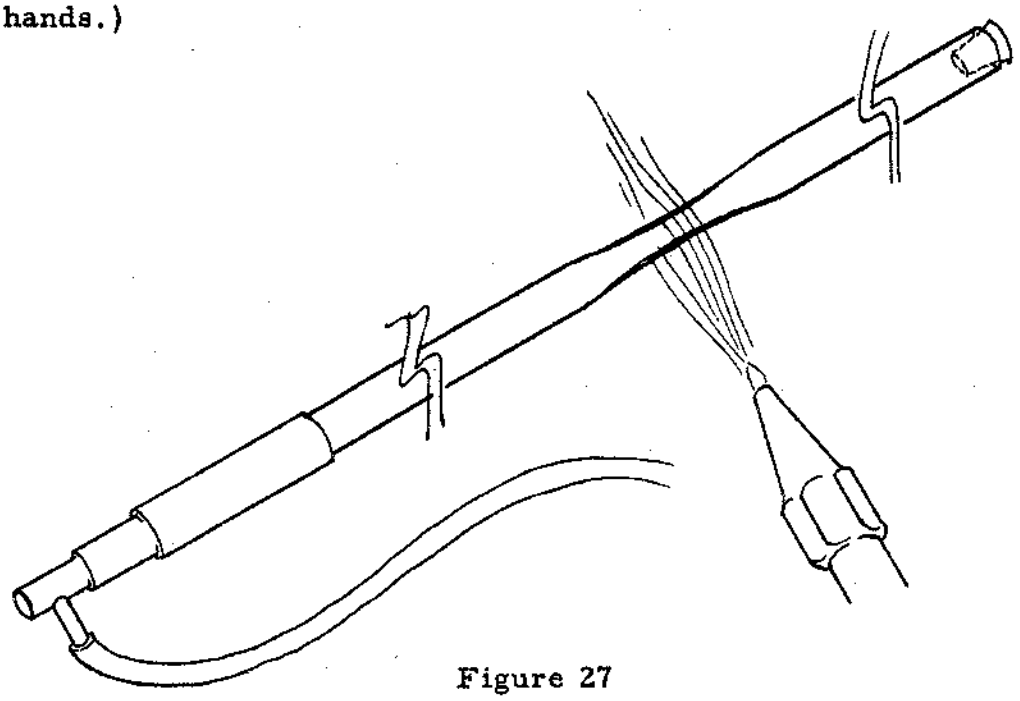


Figure 27

Now that you have heated an area 1-1/2" long, lift it out of the flame and quickly bend the two ends upward, allowing the heated portion to move downward. As soon as the bend is completed and the two ends are parallel, blow into it with sufficient force to eliminate any irregularities and at the same time expand the bent area to the original size of the tube. (See Figure #28.)

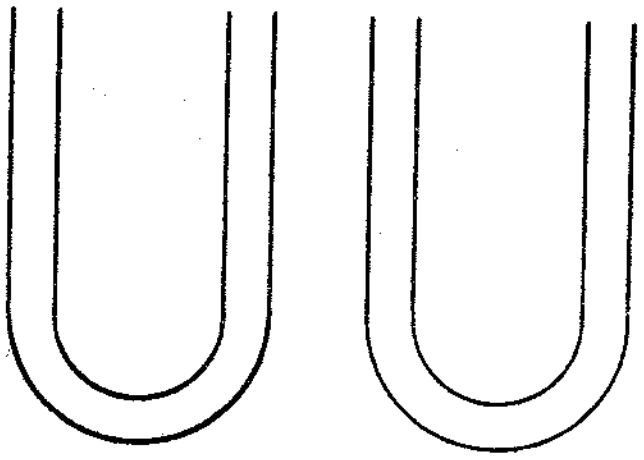


Figure 28

The trick to remember in making U bends is to always keep the tube in a vertical plane as you bend it upward. If the tube is angled away from the vertical, gravity will cause the bend to sag away from the plane of the bend, and you will have something that looks like Figure #29.

Figure 29

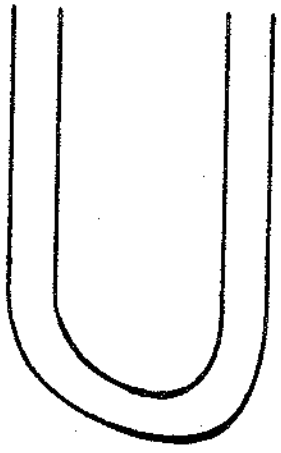


Figure 30

Also be sure to bend the two ends of the tube upward simultaneously. Otherwise, the viscous glass will tend to flow more toward one side of the U rather than the other. As the result, the U will not be symmetrical and have an uneven wall thickness, such as in Figure #30.

Furthermore, when you bend the two ends upward they should be about 1-1/2" apart. Bend quickly but do not rush. As you develop a technique for this you will find you have ample time to make the bend and the glass will still be soft enough to blow into shape. After the bend is made, blow into it to expand the tube to its original size.

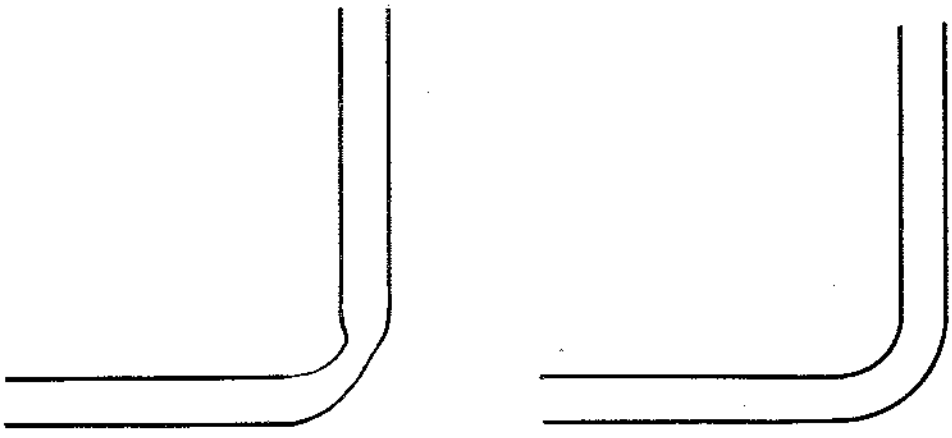
For U bends in large diameter tubing it is necessary to pull the heated area slightly just before making the bend. This eliminates any irregularities of a thickened curve on the inside of the bend. But for the sizes of glass in your set this will not be necessary.

The U bend is used in making manometers, siphon tubes and connections between two bottles of liquid.

Lesson 11

HOW TO MAKE RIGHT ANGLE BENDS

Here again coordination is vital. Choose a piece of 8 mm. tubing about 15" long. Stopper one end and put your blow hose on the other. Adjust your fire to a medium bushy flame and while rotating heat an area along the tube about 1/2" long. When the glass is soft and pliable lift out of the fire, always continuing to rotate. Hold the tube very steadily in your left hand and at the end of the tubing in your right hand. Now bend the end of the tubing upward. Do not pull upward but bend upward. If you describe an arc with the right hand you will have a nice-looking right angle bend. (See Figure #31.)



Don't pull up. Bend up

Figure 31

If after the bend is made you find that it is flat or widened out at the inside corner, you may correct it by stretching the softened tubing slightly just before making the bend. But do not blow into the glass until the bend is already made. Blow only enough to increase the diameter of the bent area to its original size. As a general rule for the sizes of tubing in your set, when making a right angle bend heat an area 1-1/2 times the diameter of tubing you are using. Heating a smaller area tends to make the bend too sharp and square. Too large a heated area tends to make the radius too large. A piece of glass tubing bent in a right angle is always useful in the laboratory. Right angle bends are used in rubber tubing connections, wash bottle connections.

(Note: Just as in making a U bend be sure to keep the tubing in a vertical plane while bending.)

Lesson 12

FIRE POLISHING AND END FINISHING

Fire polishing and end finishing are important procedures to learn because a good glassblower never leaves a raw edge on a piece of apparatus. Rough glass is as sharp as a razor and just as dangerous. No one way of fire polishing and end finishing is preferable to another -- allow the piece you are working on at the time to determine the method of finishing. End finishing actually means smoothing glass tubing so that it is never sharp, rough, jagged, or cracked.

There are a number of different ways to finish the end of a piece of tubing. Cut 5 pieces of 10 mm. tubing into 8" lengths and let's try each of them.

#1. The most common type of end finishing is simply to heat while rotating the end of a tube in the fire until it is smoothed out by surface tension. This is called "fire polishing." Do not heat enough to decrease the diameter. (See Figure #32.)

Figure 32

#2. Rotate the end in the fire until it begins to decrease in diameter and grow thick. Now lift out of the fire and insert the end of your flaring tool. As you continue to rotate, the tubing will flare out and the end will become increasingly thicker. You may either leave a thick beaded edge or flare it out. Both ways produce equally strong ends. (See Figure #33.)

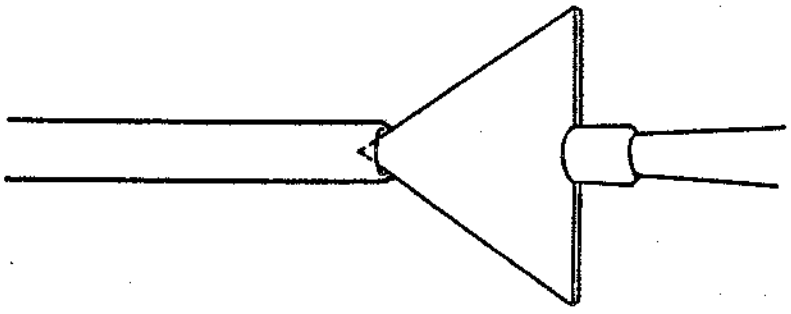


Figure 33

#3. Another way to make a beaded edge is to heat the tube until it gets thick and slightly decreases in diameter. Now, instead of flaring this out, use your flaring tool as a paddle and gently paddle the thickened glass back. Reheat and flare it to original diameter for a thickened beaded end. (See Figure #34.)

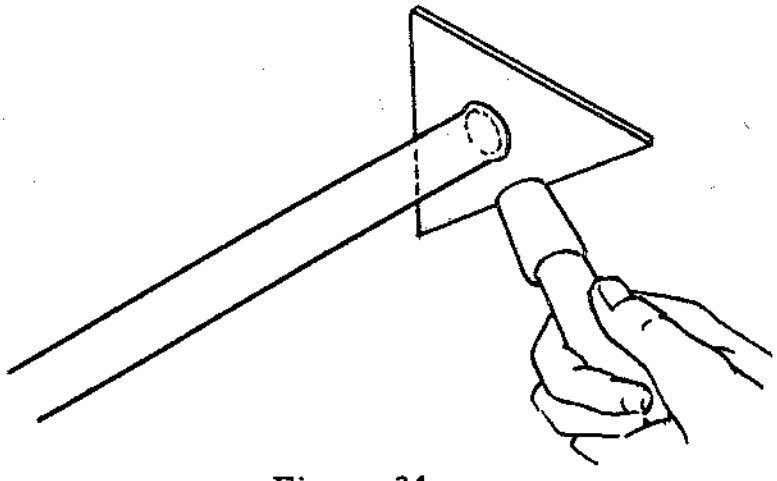


Figure 34

#4. If you have a piece of tubing with a ragged edge, heat the end until soft. Next pull it away with your tweezers, drop it back in the fire and allow it to part. Continue to rotate and heat the very tip of the end with a sharp fire and blow out a small bump. Reheat and blow the bump away. Now that you have a straight end, reheat and use your flaring tool and finish the end any way you desire. (See Figure #35.)

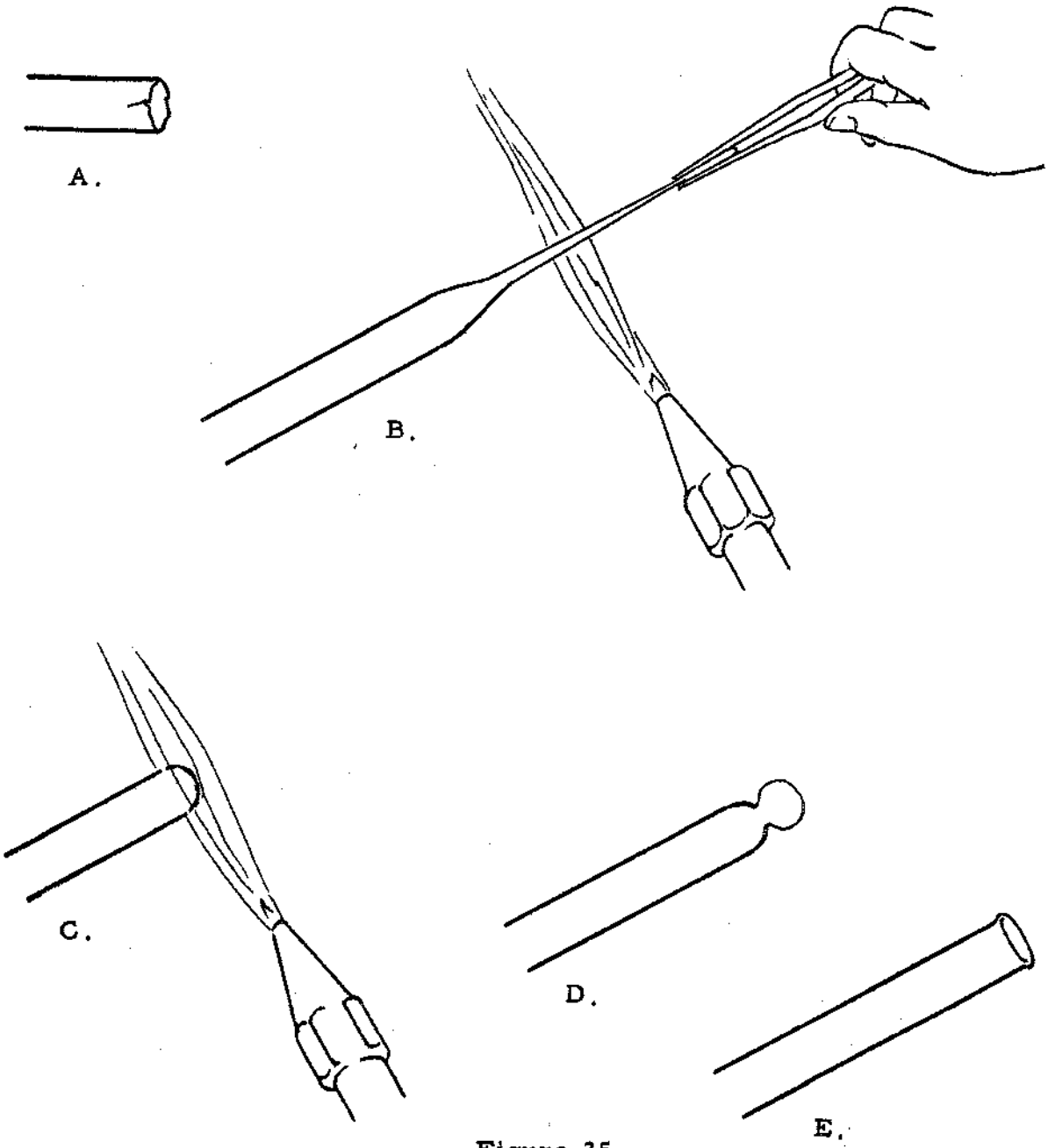


Figure 35

#5. This is another way of doing #4. Heat the end of the tube again and pull away with your tweezers. Drop back in fire and allow it to part. This time, instead of heating just the tip of the tube, heat the entire bottom until it begins to flatten and get thick. Now blow the entire bottom away, chip off the thin bulb and fire polish the flared edge. (See Figure #36.)

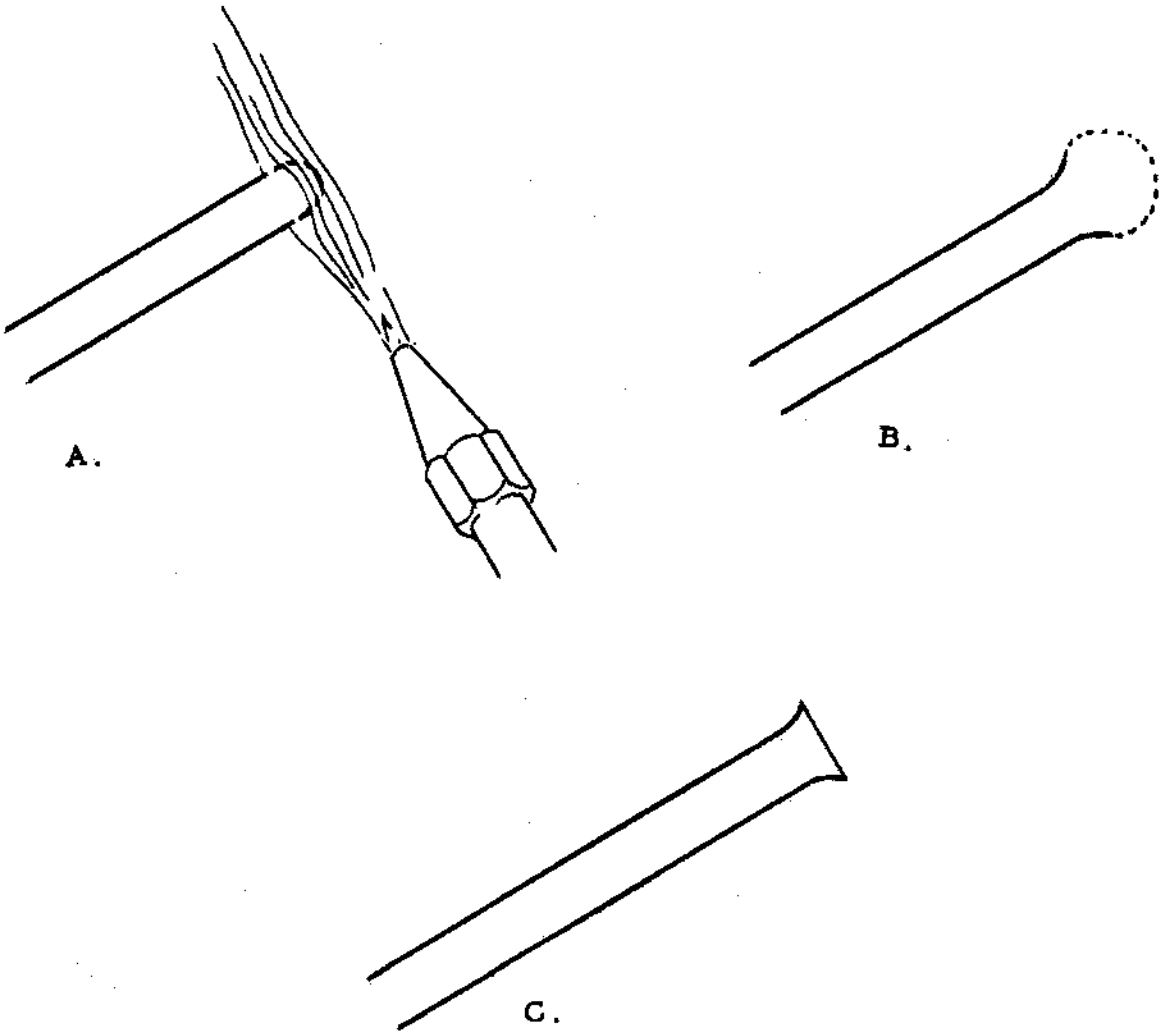


Figure 36

Lesson 13

SEALING CAPILLARY AND HEAVY WALL TUBING TO STANDARD TUBING AND TO EACH OTHER

Joining capillary or heavy-walled tubing to a piece of standard tubing is quite different from joining two pieces of standard tubing. Choose a 12" length of 8 mm. capillary from your set and put your blow hose on one end. Rotate the end of the capillary in the flame and heat it until it is completely closed off. (See Figure #37.)

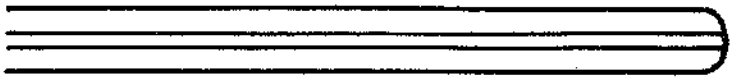


Figure 37

Now sharpen up your fire and heat the entire end of the closed capillary. When quite soft, blow enough to blow the end away. (See Figure #38.)

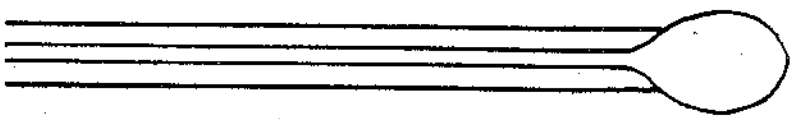


Figure 38

Now chip off the thin bulb and the capillary should look like this. (See Figure #39.)

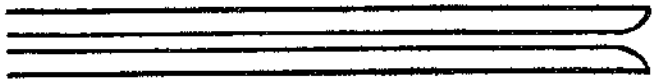


Figure 39

Now heat the thin edge of the blown-out capillary and also the edge of a piece of 8 mm. standard wall tubing about 6" long. Follow the same procedure as in making a regular seal, with this exception. The fire should never touch the heavy glass. Keep the fire right on the seal or slightly to the right of the seal. (See Figure #40.)

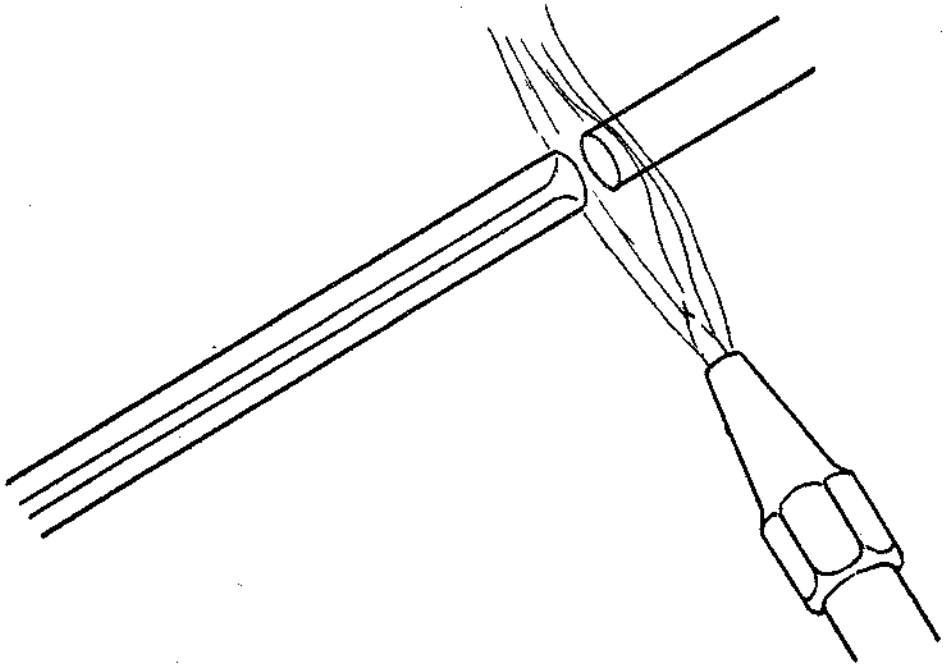


Figure 40

The reason for this is that if the capillary itself should get soft and begin to collapse it is quite difficult to blow it back out to correct size.

There are times -- such as in making a Viscometer, Flow-Meter or Check Valve -- when it is necessary to seal a piece of standard wall tubing to a piece of capillary and have a square shoulder left in the capillary. To do this take another piece of capillary and 8 mm. tubing from your kit.

Again put your blow hose on the capillary and stopper one end of the 8 mm. tubing. Heat the ends of both in a sharp fire and touch together. When heating the capillary should be heated less. Just heat the very edge of the capillary. (See Figure #41.)

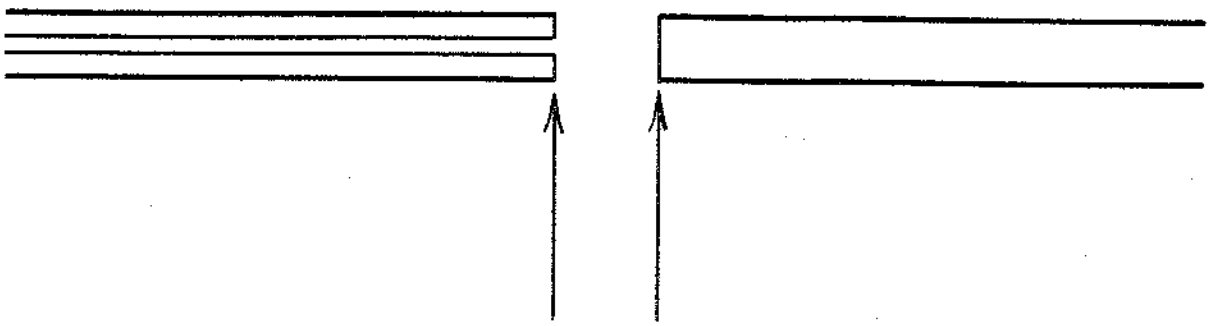


Figure 41

The 8 mm. tubing should be heated just enough to be soft but not enough to begin to collapse. Then touch them together while continuing to rotate in a sharp fire. Do not allow the fire to touch the capillary but keep it just to the right on the standard wall tubing. Heat until the edges have fused together, lift it out of the fire and blow enough to bring the standard wall tubing back to its original diameter. If this seal is made correctly the capillary will not change its inside diameter and will have a square shoulder. (See Figure #42.)

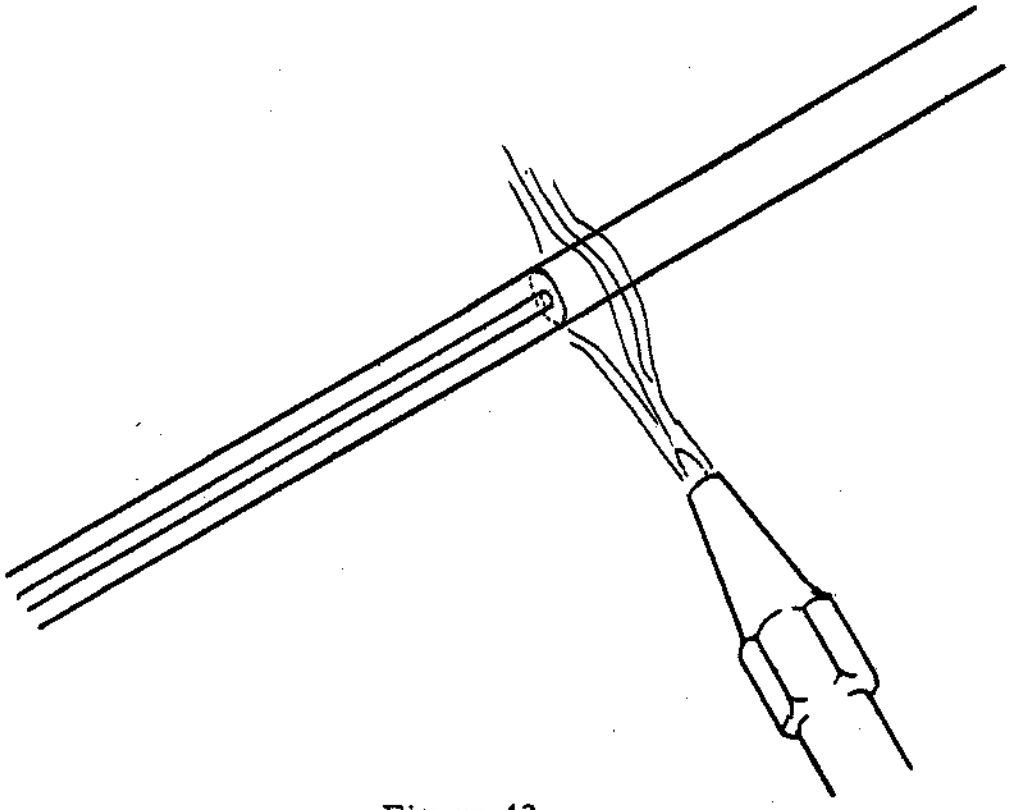


Figure 42

For a student in glassblowing, sealing two pieces of capillary or heavy wall tubing together is going to present quite a problem. But if you have steady hands and can rotate well it will not be too difficult. There are two ways of preparing the glass before the actual sealing takes place:

1. Choose two pieces of capillary about 12" long from your kit, stopper the end of one and put your blow hose to one end of the other. Adjust your fire so it is small and sharp and rotate one of the pieces in the fire until just the very end is soft. Lift it out of the fire and insert the point of your flaring tool and flare the glass slightly. (See Figure #43.)

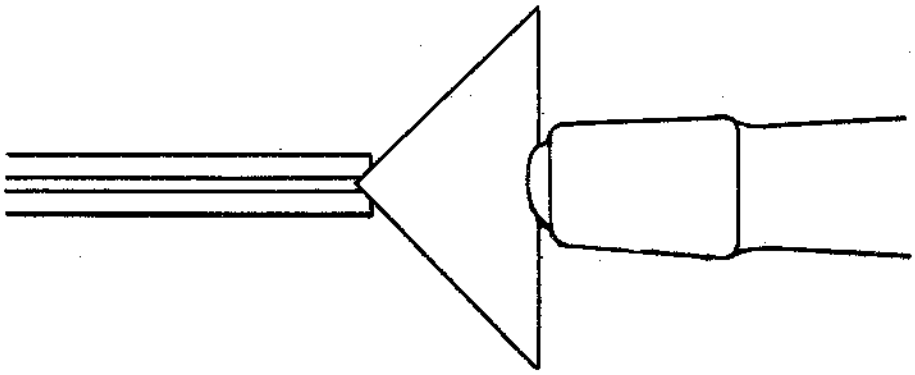


Figure 43

2. Do the same to the other piece. You are now ready to seal the two together. Rotate both open ends in the fire until they are soft and lift out of the fire and touch together. (See Figure #44.)

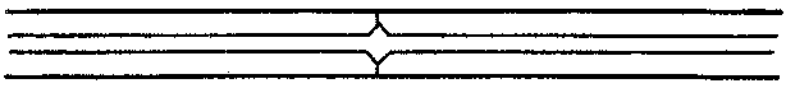


Figure 44

Now put your work back in the sharp fire and allow it to soften and begin to collapse. As soon as you notice the glass beginning to thicken and decrease in diameter take it out of the fire and blow just enough to keep it from collapsing any further. Continue to rotate all the time. If you experience any difficulty in keeping the two tubes on the same axis when touching them together, it might be better to touch the two rear edges together first. (See Figure #45.)

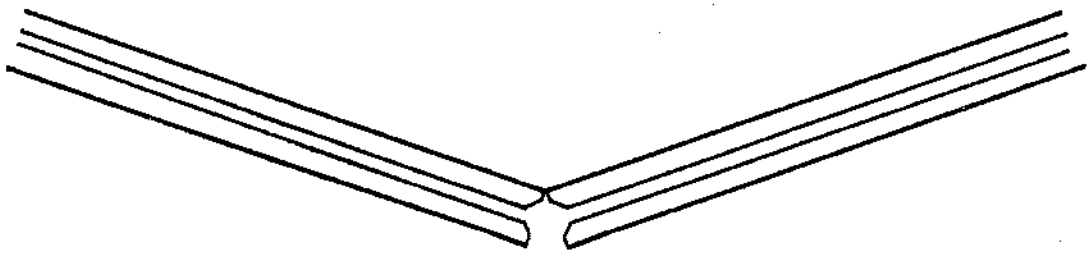


Figure 45

Now bring them together and close the gap. Finish the seal by rotating.

To join two pieces of capillary without flaring the ends takes a good deal of experience in rotating and a pair of very steady hands. Again choose two pieces of capillary tubing, stopper one and put your blow hose on the other. The open ends of these two tubes must be cut square and neatly.

Rotate them in a sharp fire until soft. Then lift out of the fire and touch together. When touching together never push or pull as this will decrease the internal diameter. Now drop back in the fire and heat until it is completely sealed. Hold just enough pressure on the blow hose to maintain the original diameter. Your greatest trouble here will be in aligning the two tubes when touching them together. They must both be on exactly the same axis. If not, you will experience great difficulty keeping the correct inside and outside diameters.

It is important to know how to make capillary seals correctly because many pieces of apparatus incorporate a piece of either heavy-walled tubing or capillary and in most cases the internal diameter of the capillary must remain constant. It cannot be smaller or larger at the point of the seal. For example, if the diameter of a Viscometer or Flow-Meter were less at the point of the seal than it was throughout its capillary length, there would be no way of computing an average rate of flow.

Lesson 14

HOW TO BLOW BULBS FOR MICRO DISTILLATION FLASKS

Blowing spheres and making capillary seals are probably two of the best coordination exercises you can practice. Both hands have to work completely in unison with one another.

Take from your set one 2-foot piece of 10 mm. tubing, stopper one end with a rubber policeman and put your blow hose on the other. Rest the tubing on your V-stand support so that your left hand is between the V-stand and the fire. Leave enough tubing extended so the right hand can grasp about 8" of it. (See Figure #46.)

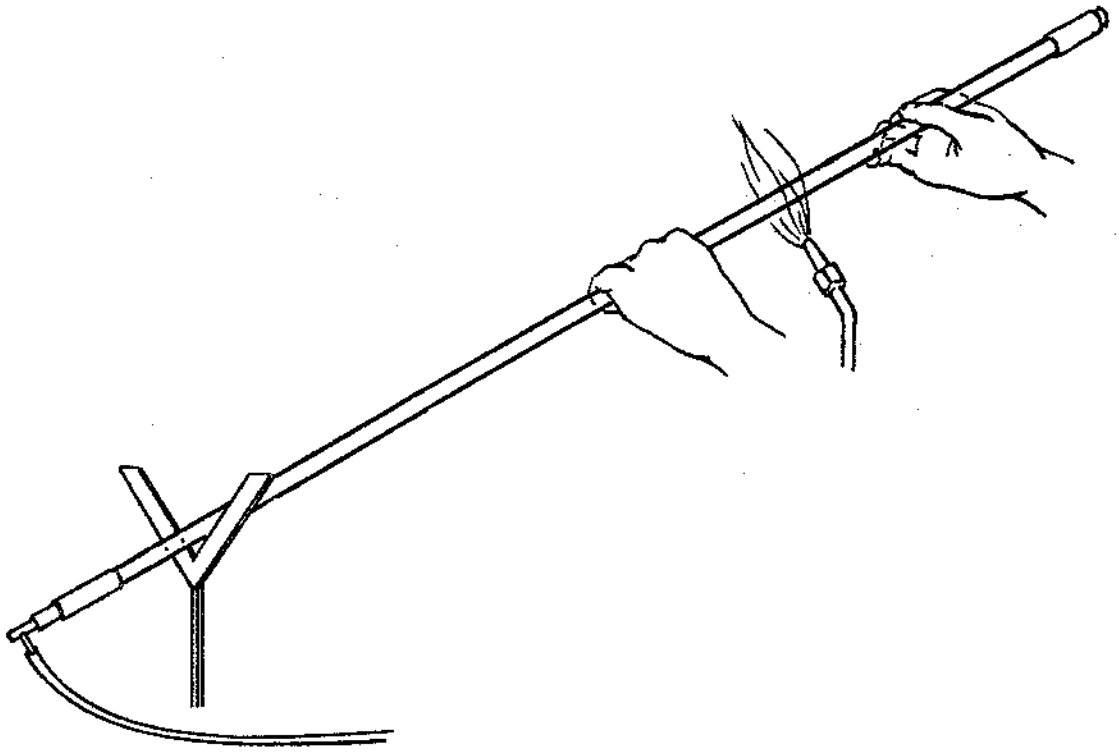


Figure 46

Now adjust your flame to a bushy fire and rotate in the flame. As the tubing begins to get soft and thicken, blow just enough to keep the internal diameter from collapsing. Feed glass into the flame from the left hand.

Do not stop rotating a moment because the glass will sag, becoming quite heavy on the bottom, and when you attempt to blow the sphere it will be lopsided. There is no set rule as to how much glass you should gather,

but bear in mind the sphere you blow should be of uniform wall thickness, so don't attempt too large a sphere at first. Having heated the desired length of glass, lift from the flame and while rotating gently but steadily blow into the tube. Do not pull or push. Allow the sphere to be blown from the area of softened glass. (See Figure #47.)

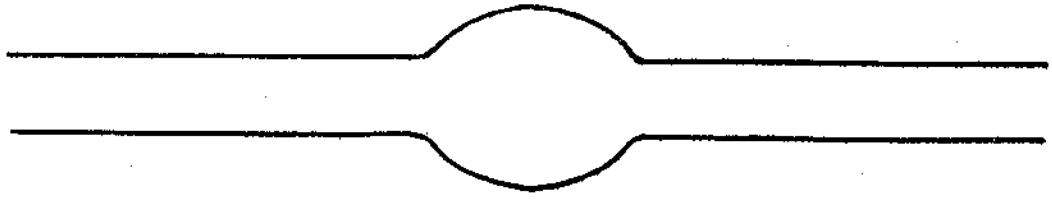


Figure 47

There are two important things to keep in mind in blowing bulbs:

1. Do not gather too much glass until you can handle a large blob of soft glass.

2. Be sure and rotate the tube at all times. If a gather of soft glass becomes misshapen due to lack of rotating, it is quite difficult to blow an even-walled bulb.

The blowing of spheres is not only an excellent exercise for coordination of the hands, but there will be times when you may be called upon to make a 2-, 4-, 6-, or 8-bulb condenser. This will involve blowing a series of bulbs on a piece of tubing which will be sealed into a larger one to make the condenser. Or perhaps you will have to make a very thin flask to contain material to be weighed. You may also be required to blow a small bulb to be used as a microdistillation flask.

Lesson 15

HOW TO MAKE STANDARD RING SEALS, COLD TRAPS, CONDENSERS

Ninety per cent of all scientific glassware involves the use of ring seals. There are many ways of making ring seals, but the easiest is the following 5-step method.

1. Select 2 pieces of 10 mm. tubing from your Glassblower's Set about 8" long. Flare one end of each as you learned to do in Lesson 12. Be sure the flare is even and square. If it is jagged or uneven, the ring seal will be lopsided.

2. Choose a piece of 20 mm. tubing about 12" long. Put your blow hose on one end and round off the other end as you learned to do in Lesson 5. The round end must be a little heavy as it will later be blown out into a small sphere.

3. In your set is a roll of 1" asbestos tape. Unroll a foot or so and wrap it tightly around one piece of the 10 mm. tube about 2" back from the unflared end. Wrap a similar piece 2" back from the flared end. (See Figure #48.)

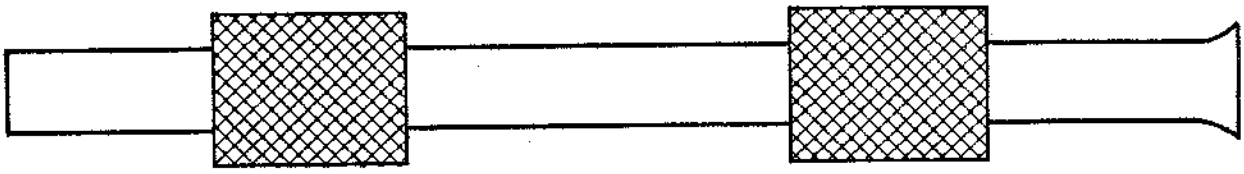


Figure 48

4. Insert the 10 mm. tube into the rounded-off piece of 20 mm. tubing so the flared end comes in contact with the inner surface of the round bottom. The inner tube must fit tightly into the outer tube and the flared end should make contact completely around the circumference. That is why the flare must be square and even. (See Figure #49.)

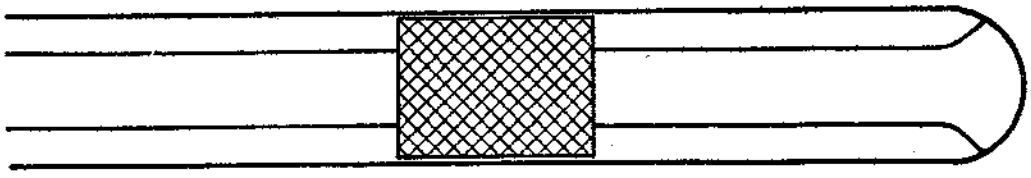


Figure 49

5. Put your blow hose back on the end of the 20 mm. tube and rotate in the fire so that the flame comes in contact with the glass at the point where the inner tube makes contact. (See Figure #50.)

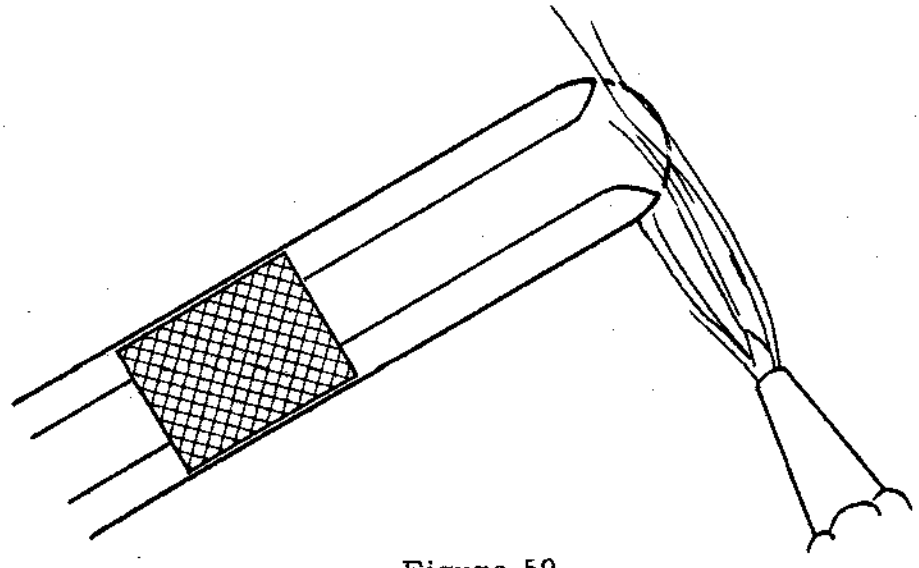


Figure 50

Allow the round bottom to shrink and become heavy and completely sealed to the inner tube. Now blow slightly until you have blown out the end. (See Figure #51.)

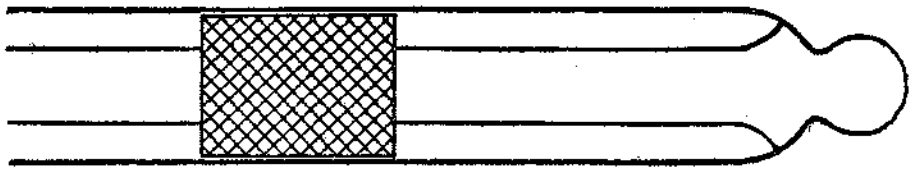


Figure 51

Next, point your flame at the very end and heat until soft and blow it away, leaving a hole of about the same diameter as the inner tube. (See Figure #52.)

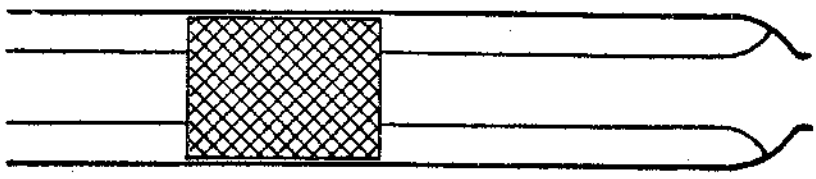


Figure 52

Now, always keeping the area hot until all seals are completed, make a straight butt seal (Lesson 6) with your other piece of 10 mm. tube. (See Figure #53.)

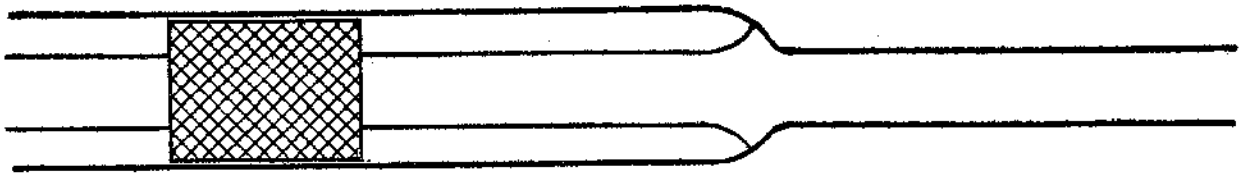


Figure 53

You have now completed a ring seal. It is rather obvious after looking at your finished piece that you are going to have difficulty in removing the asbestos tape. You should use asbestos tape only when making something that will have a side tube on it, such as a cold trap or the beginning of a condenser. Generally, making a ring seal is just the first step in making a cold trap or condenser. That is why asbestos tape has been used here. If all you are making is a ring seal alone then the inner tube can be held in place by inserting a glass tube down through it. The tube is connected with the rubber stopper that is used to blow into the outer piece, as in Figure #54. The tube should be sealed on to the rubber stopper tube following the method of Lesson 7.

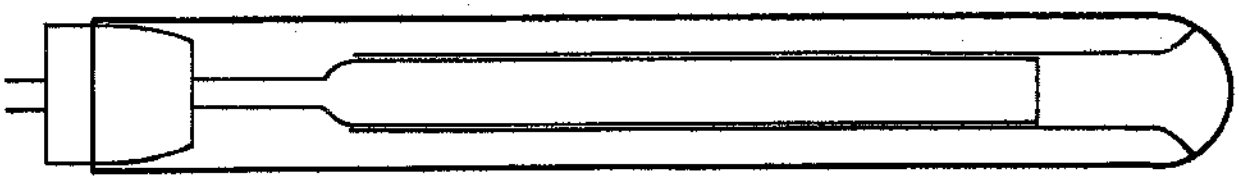


Figure 54

To make a cold trap out of the piece you have just made necessitates adding a tube to the side of the 20 mm. tubing about 1" back from the ring seal. (See Figure #55.) The procedure here is the same as making a T seal (Lesson 8). After joining the side tube the whole area should be annealed. To do this heat the entire area around the ring seal and side tube in a bushy fire from your annealing burner until the glass looks slightly red in color. Cool slowly by decreasing the amount of air. After your work is cold, flush out the asbestos by running water through the side tube, forcing the asbestos down and out. Dry out all excess water and put your blow hose on the 10 mm. tube extending from the ring seal. Stopper up the open end of the side tube. Now turn the entire piece of apparatus around so the 10 mm. tube extending from the ring seal is now held to your left hand and the larger tube is resting on V-support in a position so that your flame will strike the tube about 1" below the point where the inner tube ends. Heat the end of the 20 mm. tubing until soft and pull it off into a round bottom. You now have a cold trap. (See Figures #55 & #56.)

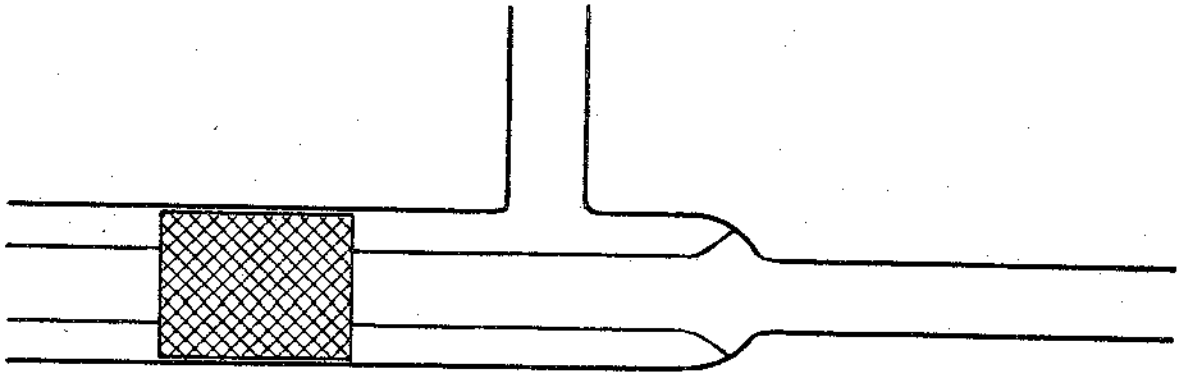


Figure 55

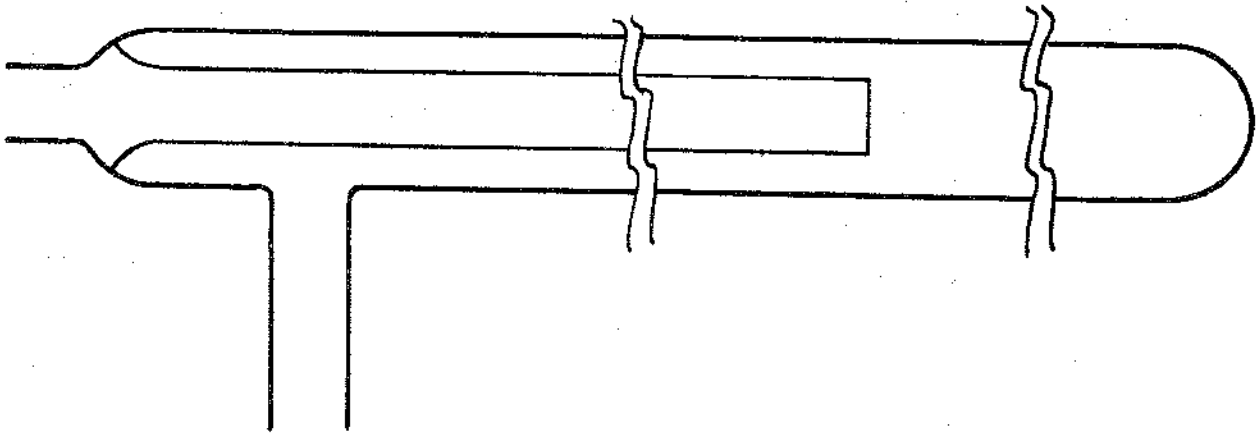


Figure 56

To make a condenser, proceed through all the steps of making a cold trap up to and including side tube. The only difference is that the inner tube should be flared on both ends. (See Figure #57.)

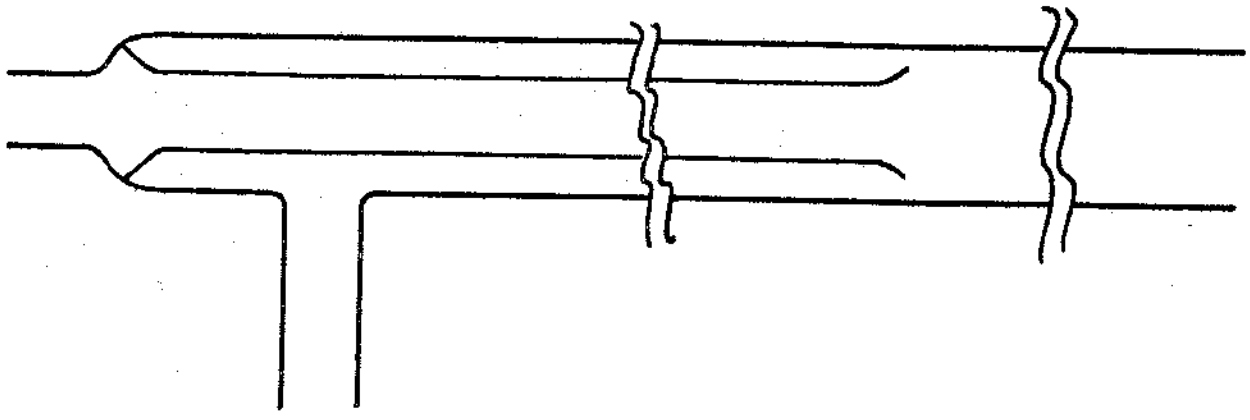


Figure 57

Now instead of rounding off the outer tube as you did for the cold trap, soften the end of the outer tube and pull it off into a point and fasten a glass rod to it as a handle. (See Figure #58.)

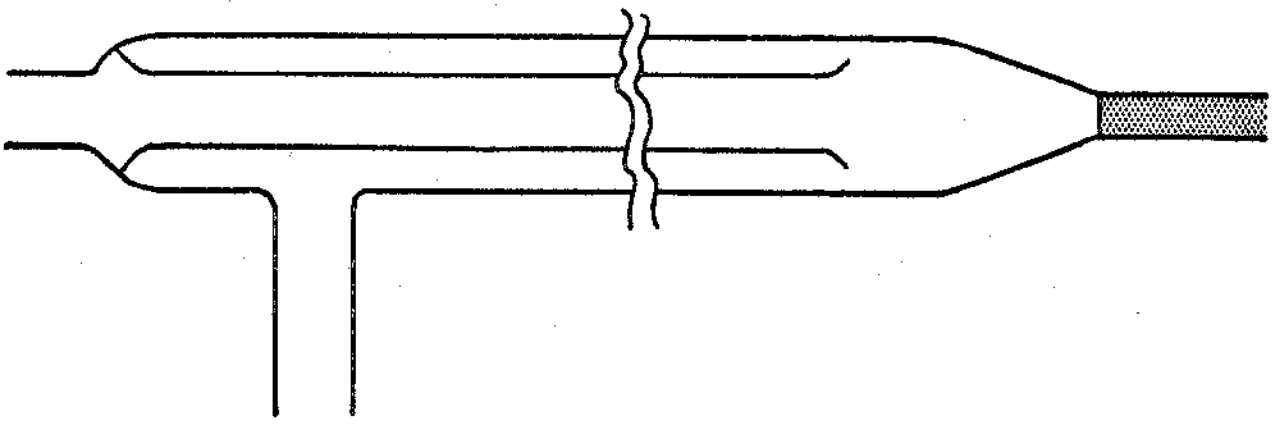


Figure 58

Move your work so that the fire is directly over the flare and heat until the outer tube collapses down and makes contact with the flare. (See Figure #59.)

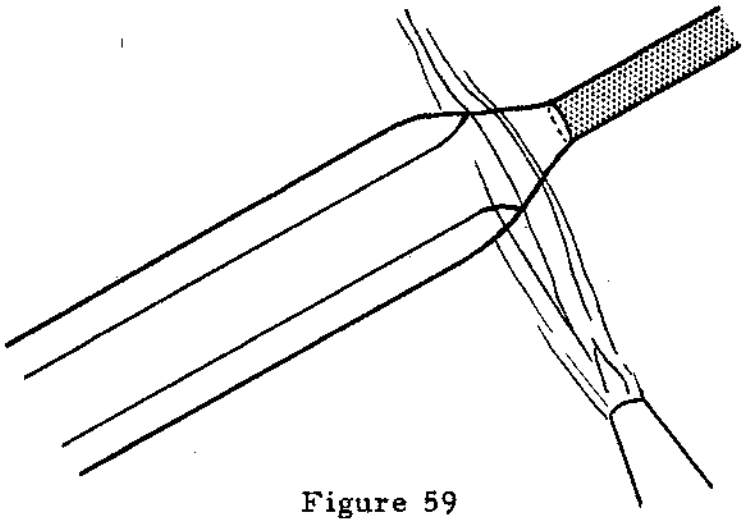


Figure 59

Pull the excess glass to the right of the seal away. The end should now look like Figure #60. The heat has now separated the rod from the end of the tube.

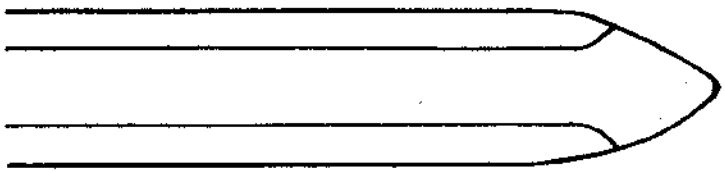


Figure 60

Next take the blow hose off the 10 mm. tube and put it on the side tube. Heat the end by turning backward and forward and blow gently until the outside tube is nice and round. (See Figure #61.)

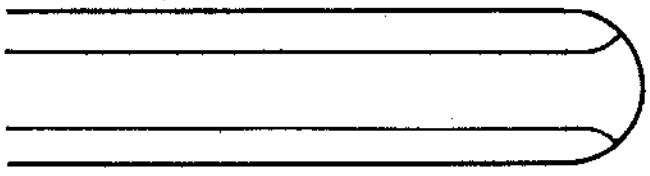


Figure 61

Now seal on another side tube 1" back from the new ring seal. (See Figure #62.)

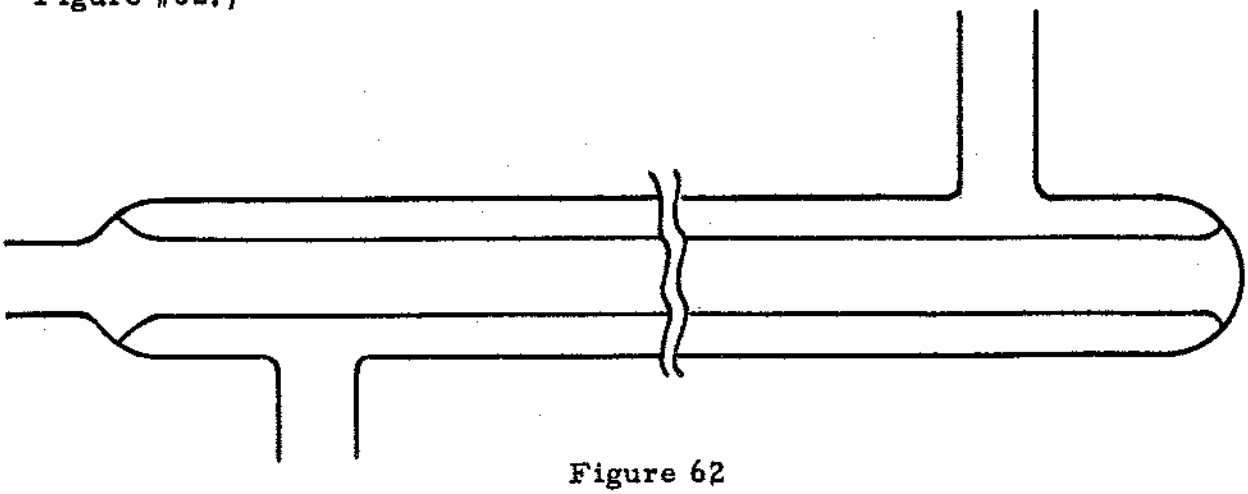


Figure 62

Without wasting any time put your blow hose back in the 10 mm. tube, heat the extreme end and blow out a hole the same diameter as the inside tube. Butt seal on another piece of 10 mm. tubing. (See Figure #63.)

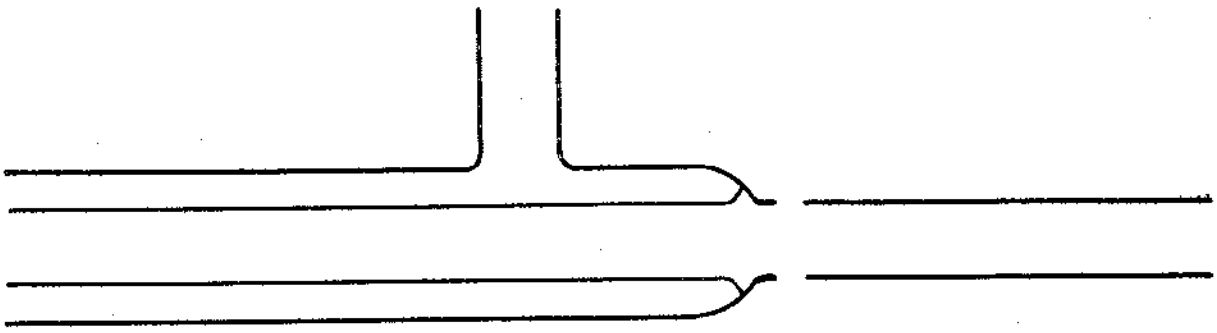


Figure 63

You now have a condenser. (See Figure #64.)

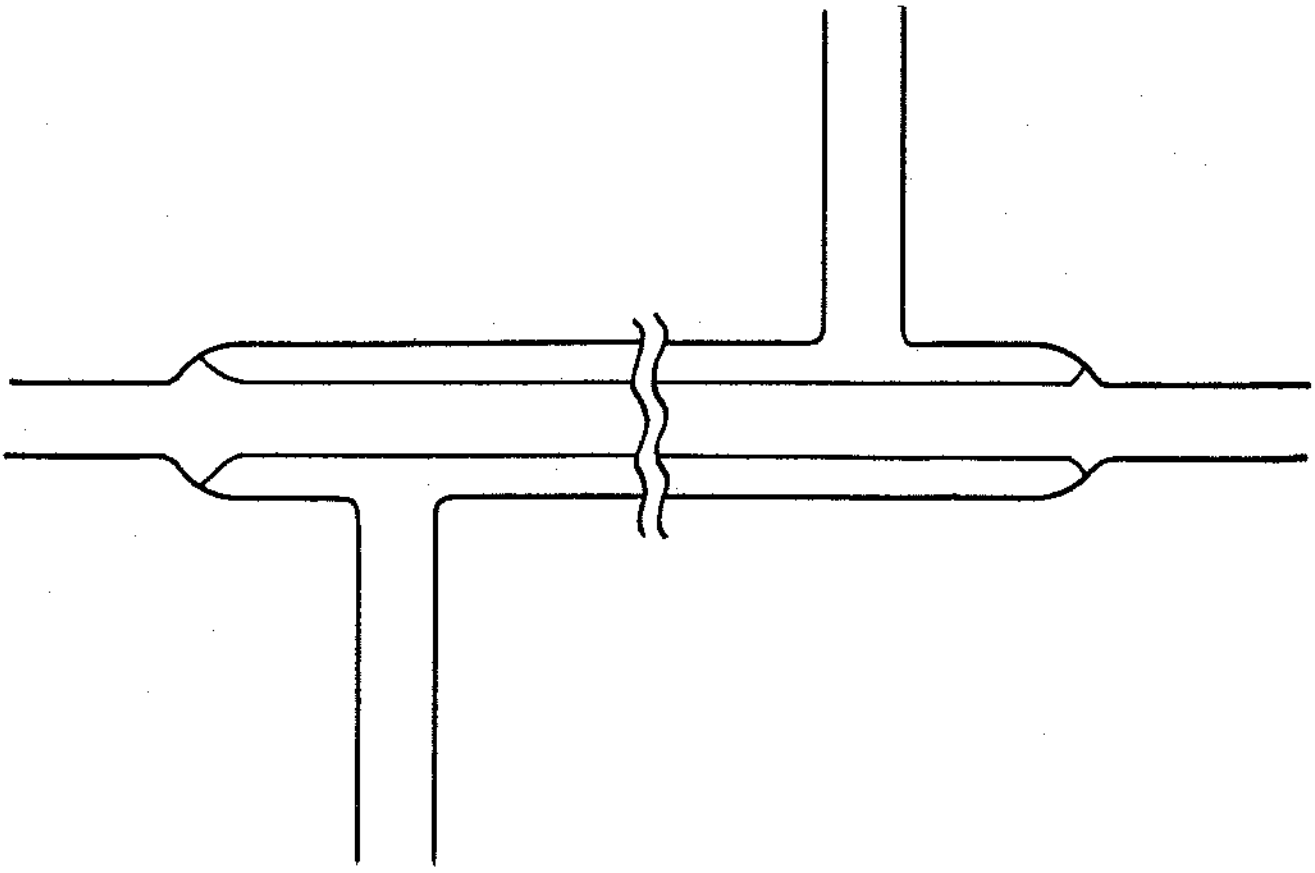


Figure 64

The ring seal is a very important part of a scientific glassblower's training. A poor ring seal, uneven and not uniform in wall thickness, not only looks bad but can and will crack when subjected to thermal shock. A good example of this is the ring seals incorporated into a mercury diffusion pump -- when you have hot mercury vapor surging through the inside tube while cold water is circulating around the outside by means of a water jacket, the ring seals at either end are subjected to severe strain. If part of either seal is too thick or too thin, the seal can very easily break. Ring seals are generally always used to suspend one tube inside another.

Lesson 16

HOW TO MAKE INSERTION-TYPE RING SEALS

This type of ring seal is modified so that a very short length of tubing may be sealed on the inside. It is particularly suitable in those cases in which it is not convenient to use a flared tube as the inner tube.

1. Round off a piece of 20 mm. tube about 12" long. In the rounded end, blow a thin bulb, crack the bulb off, and form an opening with a beaded edge about 10 mm. in diameter. If the hole is blown too small ream it out with your flaring tool. (See Figure #65.)

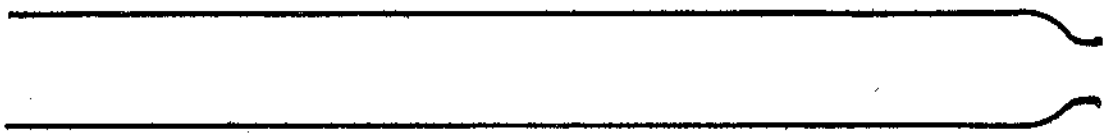


Figure 65

2. Choose a piece of 8 mm. tubing and rotate slightly to the right of center in a sharp fire until soft. Take it out of the fire and push together slightly. (See Figure #66.)

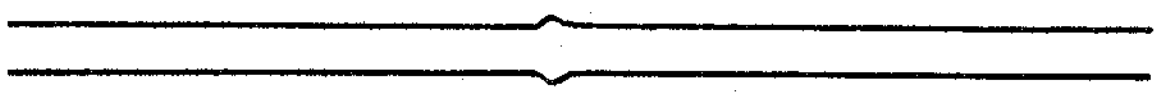


Figure 66

Then cut off the short end about 3/4" from the ridge. (See Figure #67.)

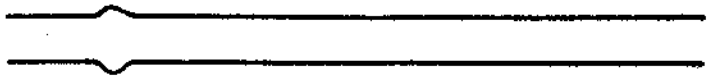


Figure 67

3. Hold the large tube in the left hand and rest one end in your V-stand support. With the right hand insert the 8 mm. tube into the large tube until the ridge is against the edge of the 10 mm. hole. (See Figure #68.)

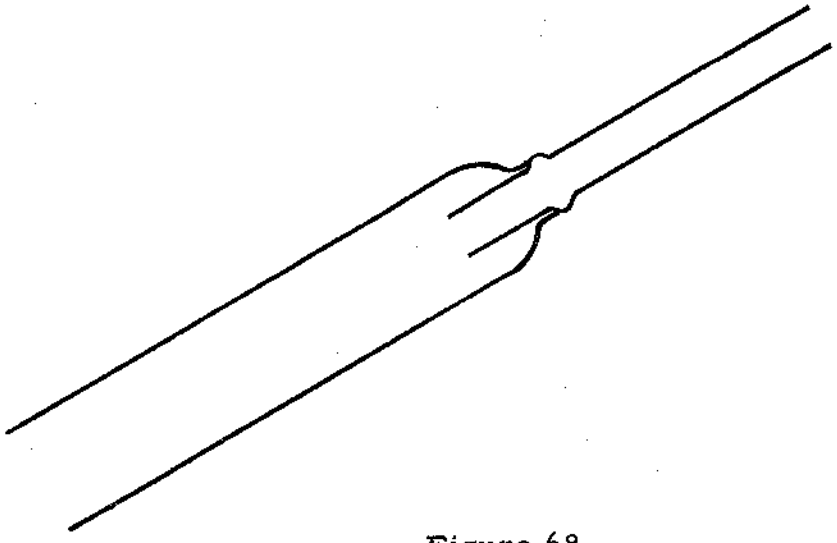


Figure 68

Rotate in a sharp fire with the flame pointed at the ridge and opening. Heat until completely fused and then blow slightly to reform a rounded edge. (See Figure #69.)

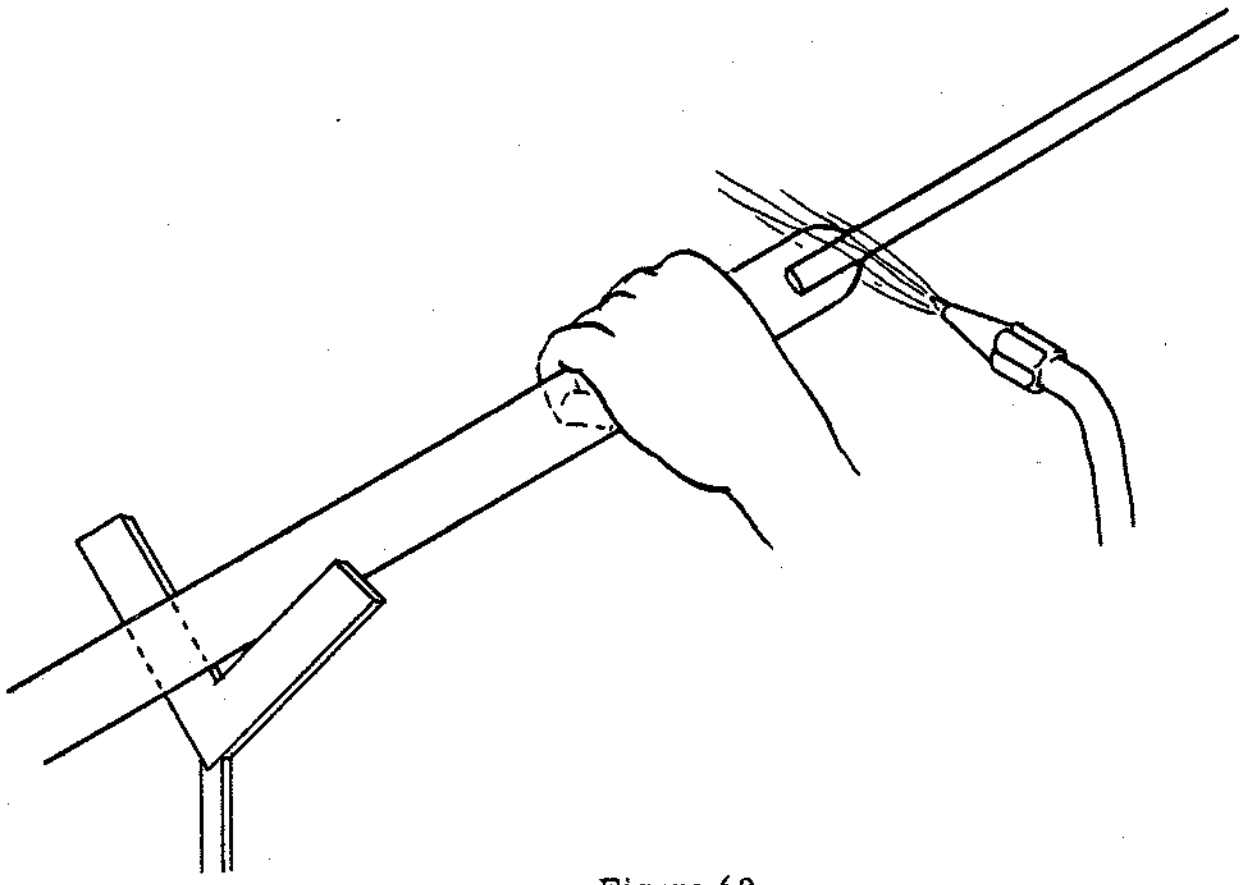


Figure 69

If the small tube in your right hand should become thick, pull and blow gently until it has the correct diameter. If the inner tube is not straight reheat in a bushy flame and rotate until it becomes straight. This may take a little maneuvering but if you rotate long enough it will straighten itself out.

This type of ring seal may be used whenever a short length of tubing is suspended inside a larger one. Mercury and oil traps for vacuum lines are quickly made by using this type of seal.

Lesson 17

CLOSED CIRCUITS OF GLASS TUBING, FLOW METERS

It is often necessary to seal both ends of one tube to another tube. In this case you make the first seal a standard T seal, or bend the tube to be sealed on into a 90° angle first and then make a T seal.

1. Choose a 10" piece of 25 mm. tubing from your set. Stopper one end and put your blow hose on the other. Mark the tube with a grease or soapstone pencil where the two holes are to be made. Hold the tube in the flame as you learned to do when making a T seal. Blow out a hole about 8 mm. in diameter.

2. Take a piece of 8 mm. tubing about 6" in length and either make a standard T seal to the 25 mm. tube or first bend it to 90°. If you bend the tube first it will be much easier than attempting to make the same bend after the tube is sealed vertically to the 25 mm. tube. (See Figure #70.)

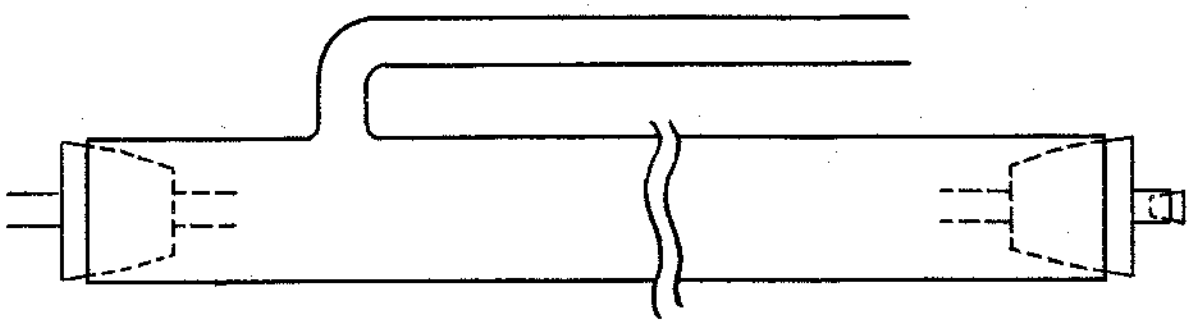


Figure 70

3. Blow out the second hole at the desired marked point. Now cut the 8 mm. tube long enough so that after a bend it will make contact with the open hole as in Figure #71.

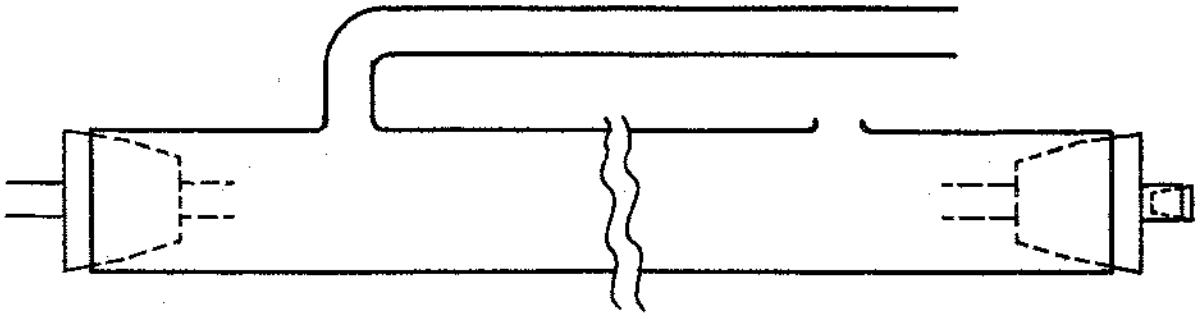


Figure 71

Now adjust your flame to a medium bushy fire and heat the area on the 8 mm. tube at the point where the bend is to be made. At the same time heat the end of the 8 mm. tubing and the hole in the large tube.

With your tweezers grasp the small tube near the end and bend it down so that the open end comes in contact with the hole in the large tube. (See Figure #72.)

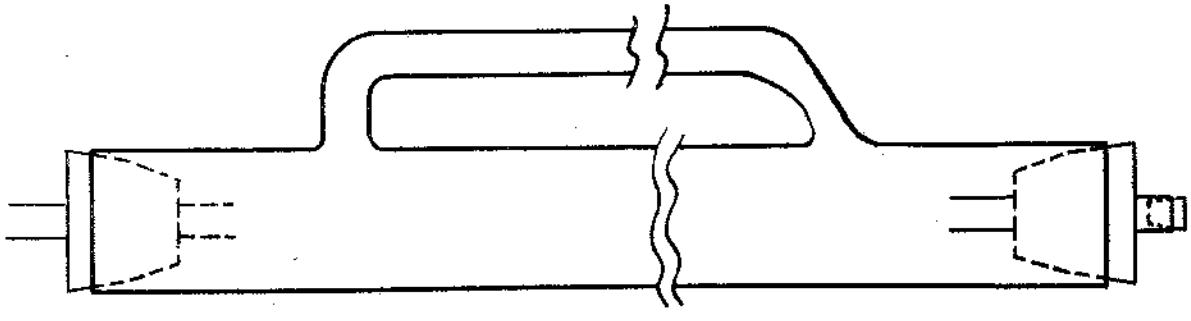


Figure 72

If, after the bend is made, you find you have not made complete contact with the opening in the large tube, reheat the immediate area and close any small holes by "picking" or pushing the hot glass with a small length of Tungsten wire, which is supplied in your set.

4. Adjust your fire again to a small sharp flame and reheat the bend and blow it out to correct size and diameter. Then reheat the seal between the 8 mm. and 25 mm. and blow it to correct size and shape. (See Figure #73.)

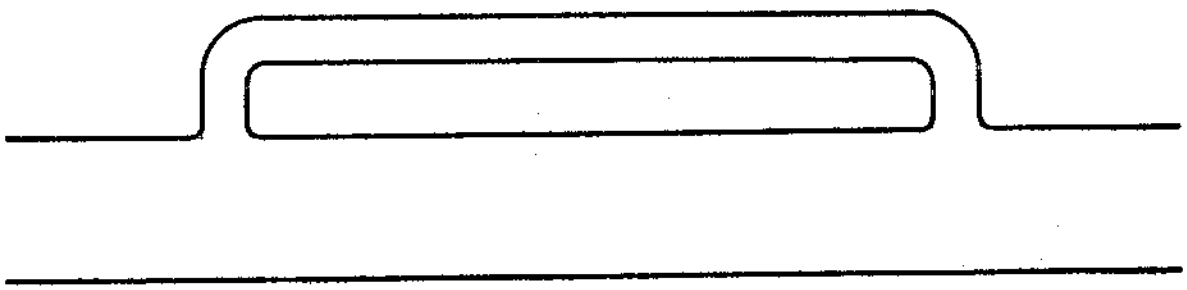


Figure 73

5. When you become an experienced glassblower, you will be able to make both bends to measure and then join the open ends to the larger tube. This is a method preferred by some glassblowers when the distance between the bends is short.

Lesson 18

HOW TO WIND AND WRAP COILS, CONDENSING SPIRALS, EXPANSION MEMBERS

Glass coils are best wound on a mandrel. The mandrel may be made from an iron or brass tube or rod. A slot or hole cut in one end serves as a convenient means of holding the glass tubing. (See Figure #74.)

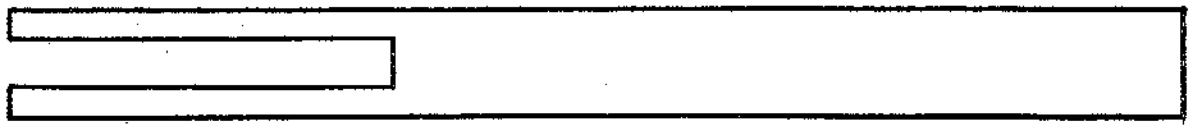


Figure 74

Obtain a suitable mandrel about 12" long and 1" in diameter. Cut out a 1/4" slot. Wrap the end opposite from the slot with some asbestos tape. This keeps your hand from getting too hot. Now take an 18" length of 8 mm. tubing and put your blow hose on one end and close off the other end. Insert the closed-off end into the slot of your mandrel. Hold the mandrel in the right hand with the tubing perpendicular to it in the left hand. You may rest the weight of the mandrel on your V-stand support, as in Figure #75.

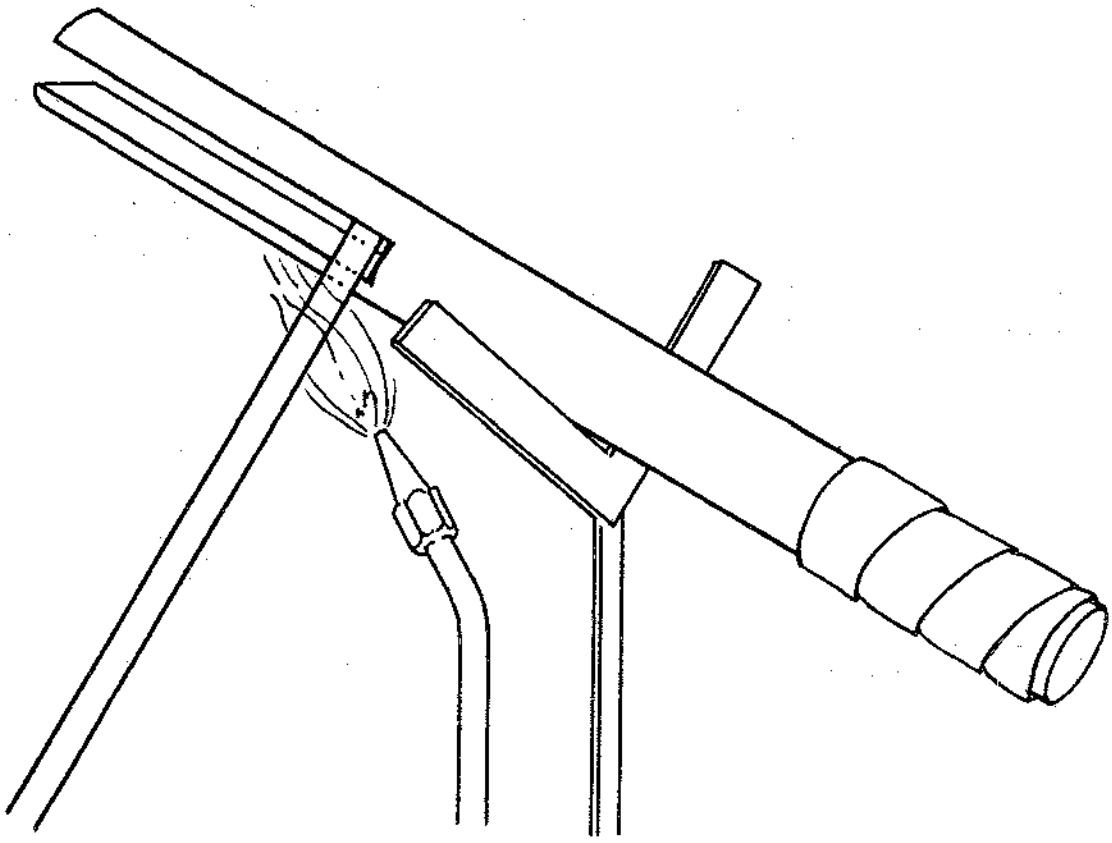


Figure 75

Adjust your fire to a large bushy flame and play it on the glass near the mandrel. Wind the tube slowly as it softens. Blow just enough to keep the glass from flattening, being sure that your coil is spiraled evenly. (See Figure #76.)

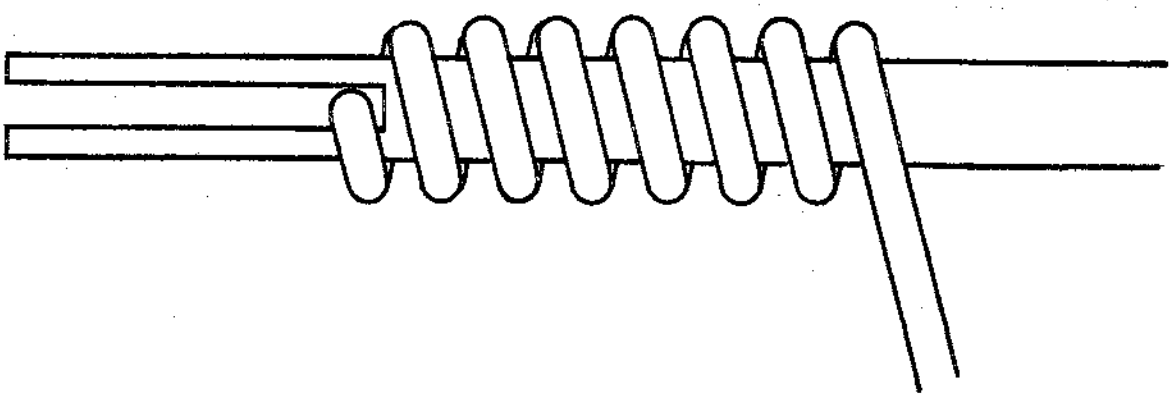


Figure 76

A more effective method of winding a coil is done with a ribbon burner. You can make a simple form of ribbon burner with a piece of 1-1/2" pipe about 12" long with a gas and air inlet on the bottom. Drill about 50-1/64" holes in the top. Then mount it on a stand so it sets about 8" above your bench. (See Figure #77.)

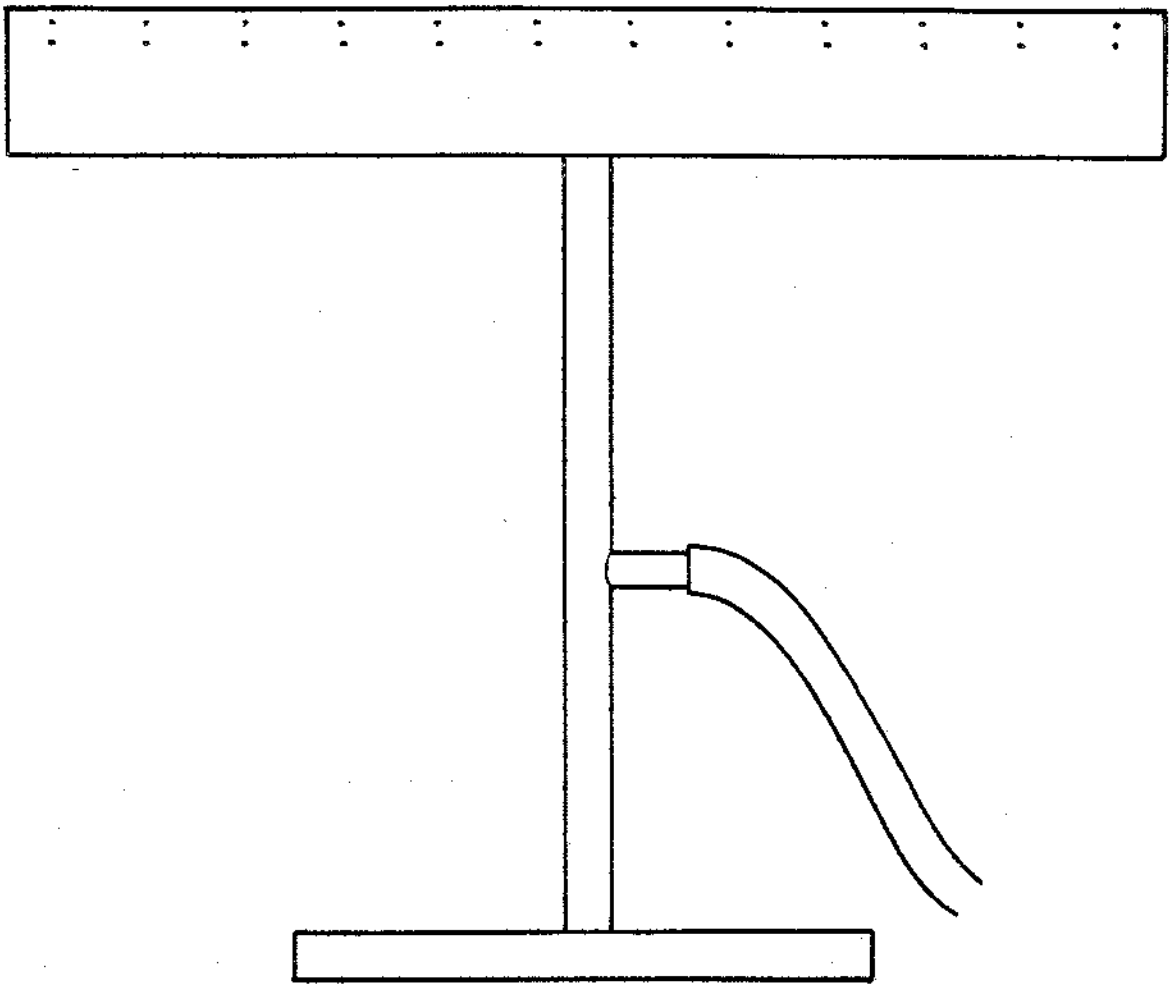


Figure 77

When using a ribbon burner, rest your mandrel in the V support so that the slotted end is over the end of the burner. The glass should extend down over the length of the burner, as in Figure #78.

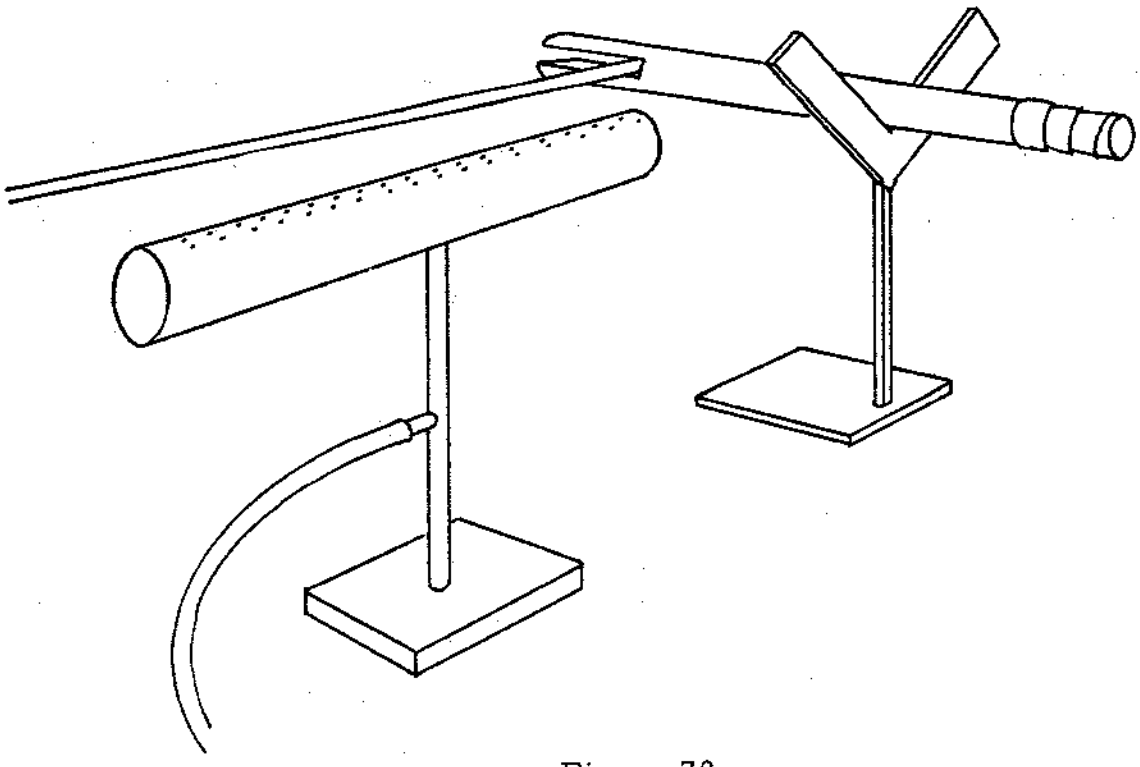


Figure 78

The bottom of the glass tubing should be about 1-1/4" above the burner. This enables the flame to completely envelope the tube, making it soft over an 8 to 10-inch length. As the glass becomes soft, begin turning the mandrel, counter clockwise, wrapping the glass always from the underside of the mandrel. If this is done correctly, very little blowing is necessary. The soft glass tube will conform to the mandrel without collapsing or getting flat in certain areas. A good deal of skill is required to wrap a coil with a ribbon burner. You have to feed 8" to 10" of soft glass continuously onto the mandrel. In the method given in the first part of this lesson, however, there is only 1/2 to 3/4" of hot glass to be contended with at any given time.

Coils are used as expansion members between two rigidly fixed pieces of glass -- also as condensers. Coils wound from small diameter rods make good distillation column packing.

Lesson 19

DEWAR SEALS AND DEWAR FLASKS

Dewar Seals are a type of seal where one tube is usually suspended inside another and sealed at one end. The name Dewar generally means a vacuum flask. An example is the ordinary thermos bottle. The seal at the top where the inner glass tube is sealed to the outer is a Dewar Seal. An object that looks like a thermos bottle is called a Dewar Jar. A Dewar Jar is used for practically the same purpose as a thermos bottle and comes in various sizes and shapes. Here you will be mainly concerned with how to make a plain Dewar Seal.

Choose from your set two pieces of tubing, one 25 mm. about 10" long, the other 15 mm. about 6" long. On the 15 mm. tube put a round bottom on one end and a slight flare on the other. (See Figure #79.)

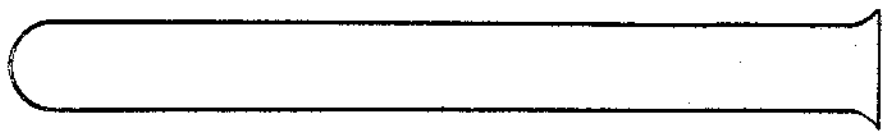


Figure 79

From the 25 mm. tube cut off one end so that it is perfectly square. Put your blow hose on the other end. (See Figure #80.)

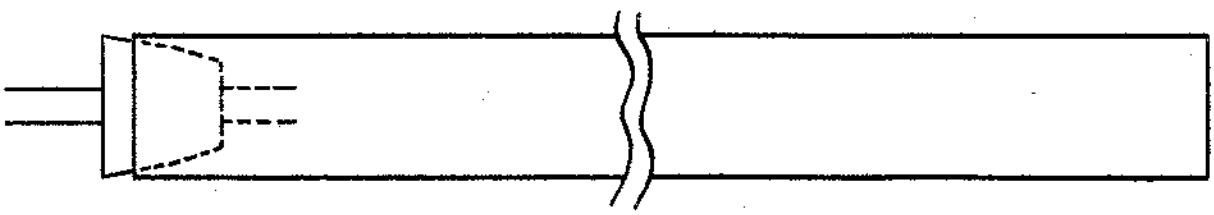


Figure 80

Now wrap the 15 mm. tube in two places just as you did when making a ring seal. At the same time be sure the asbestos wrapping on the flared end is about 2" back from the flare. (See Figure #81.)

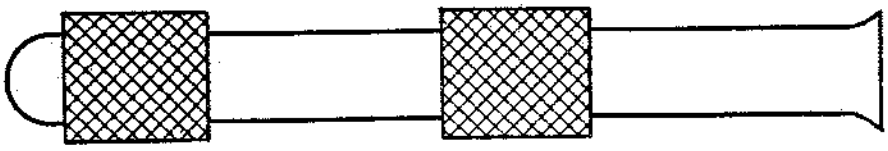


Figure 81

Insert the wrapped tube into the larger tube, making sure that it fits tightly. If the fit is sloppy your Dewar Seal will be poor. Now that you have the small tube inside the larger, position them so the flare on the small tube is perfectly square with the end of the larger tube. (See Figure #82.)

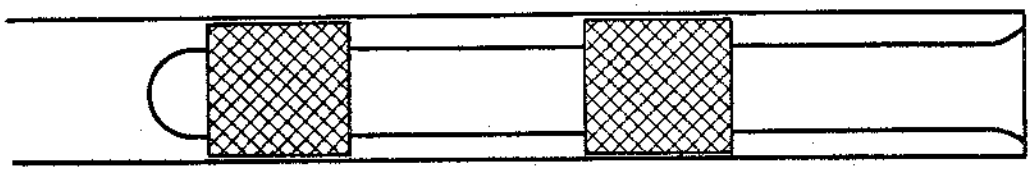


Figure 82

Now place your work in your V support so that the support is close to your burner. (See Figure #83.)

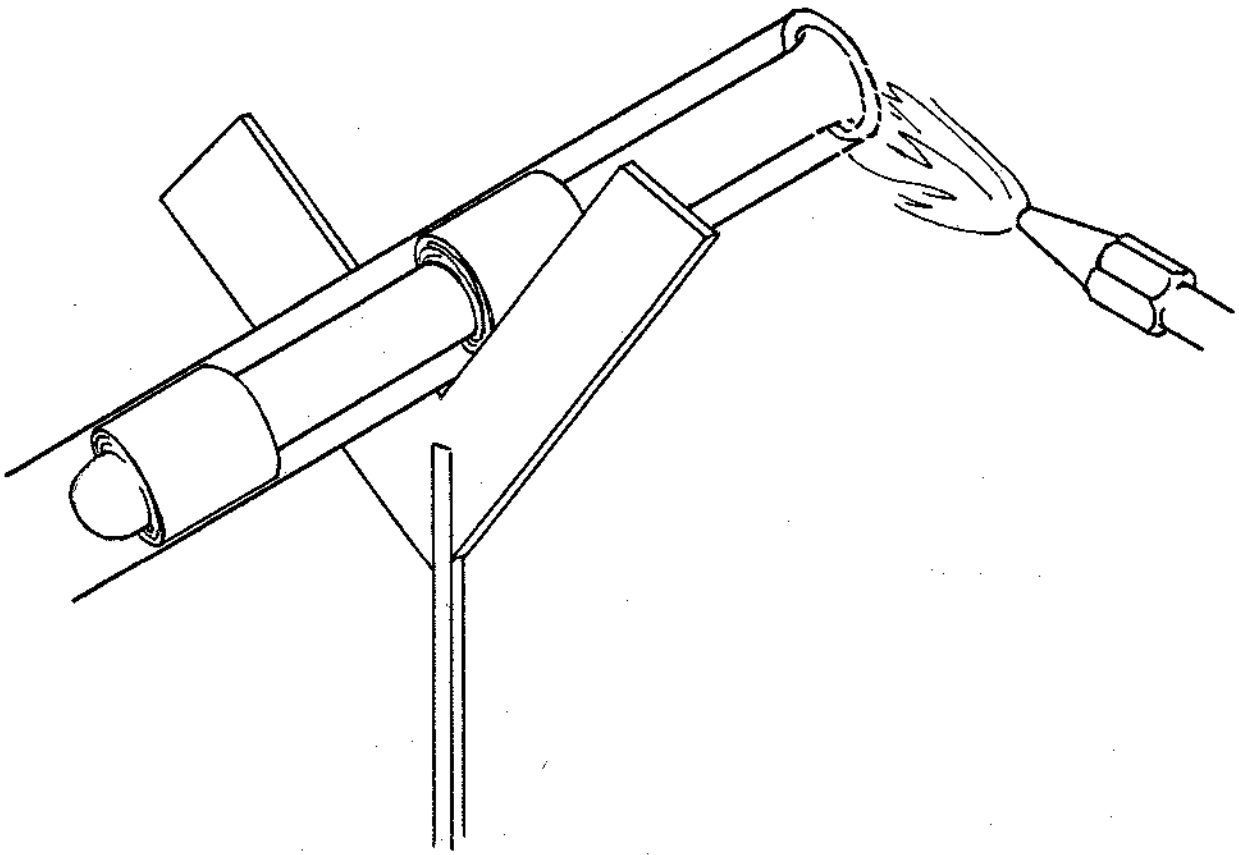


Figure 83

Take your flaring tool in your right hand and hold as a paddle. Rotate your work in a medium bushy fire. Have the flame pointed at a slight angle to the edge of the glass. (See Figure #84.)

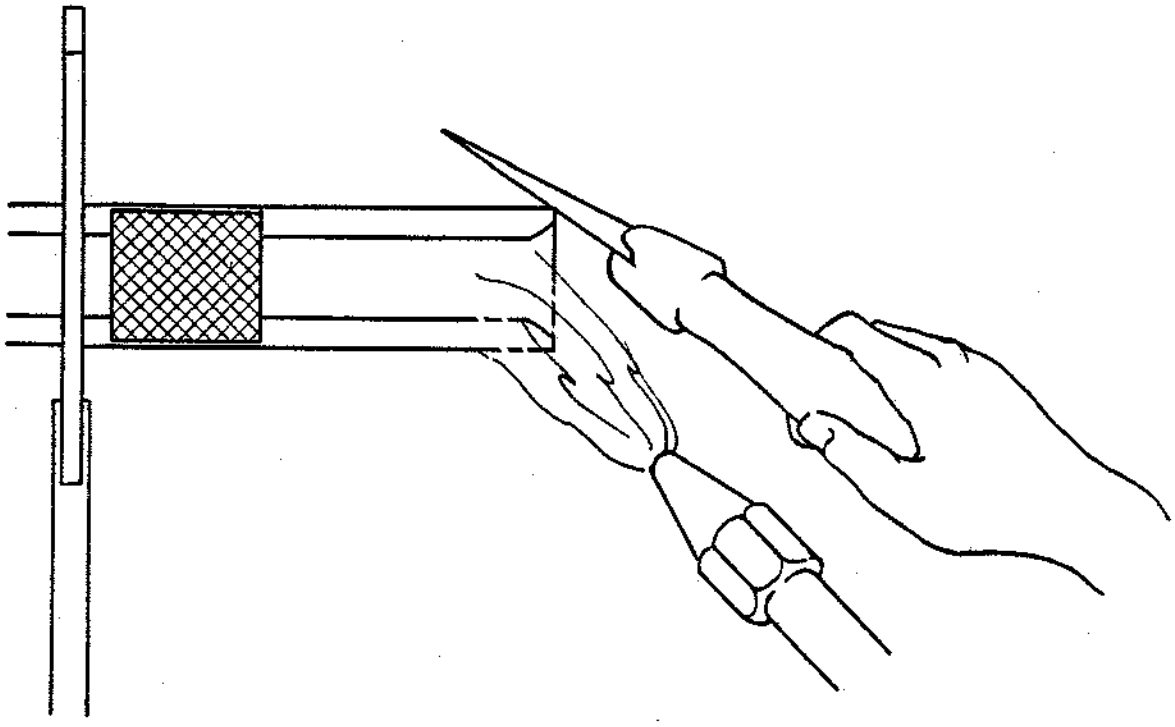


Figure 84

Continue to rotate until the end of the large tube begins to soften. Now rest your paddle on the top of your work and push slightly, continuing to rotate at all times. The soft outer tube will bend down and touch the flare of the inner tube. After complete contact has been made all the way around, take away your paddle and continue to heat. As the two pieces of glass fuse together, blow very gently -- just enough to make a well-rounded end. (See Figure #85.)

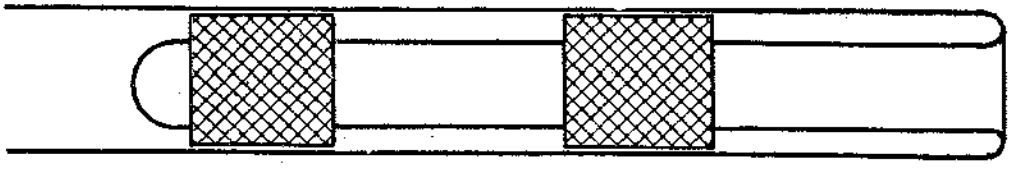


Figure 85

If, in the heating and blowing process, you note that the inner tube is getting smaller in diameter, insert your carbon rod and bring it out to correct size. If good contact is made as you are paddling down the larger tube, very little blowing is required. To finish this up as a miniature Dewar Jar, seal a small tube about 1/2" back from your Dewar Seal at right angles. (See Figure #86.)

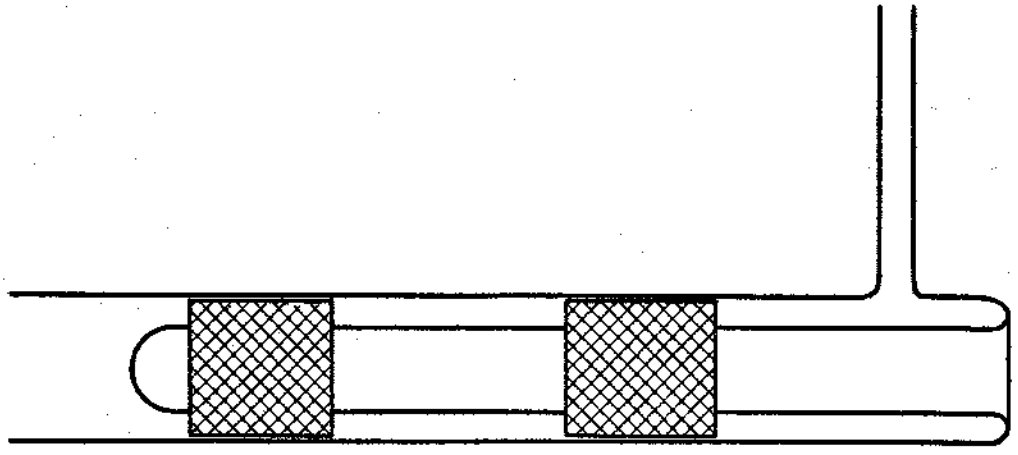


Figure 86

Anneal your work in a bushy gas-air fire just as you did for a ring seal. When it cools flush out the asbestos and make a round bottom on the 25 mm. tube. (See Figure #87.)

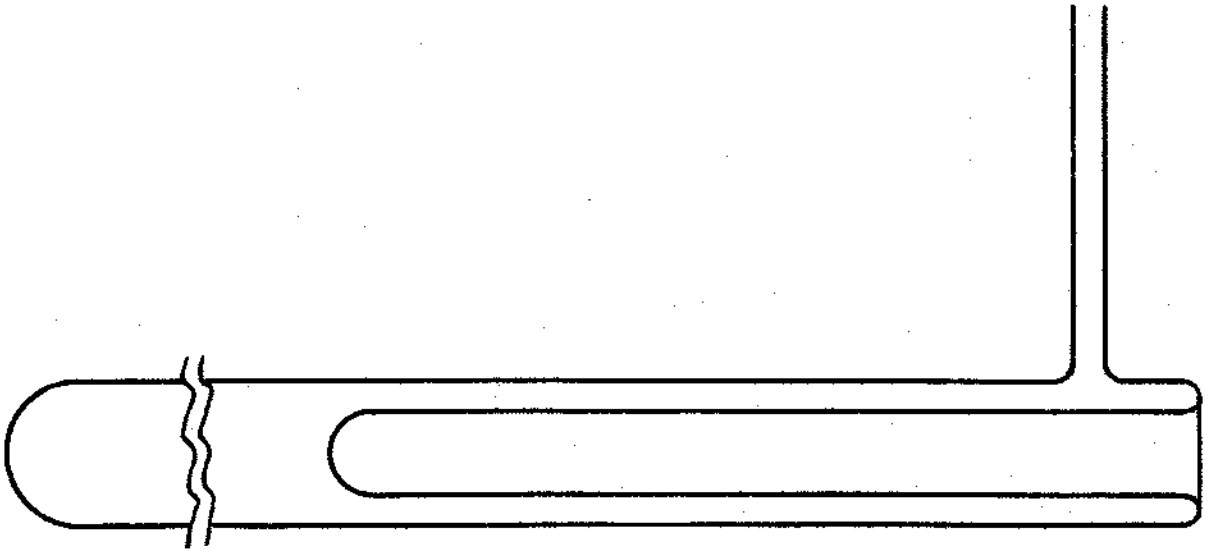


Figure 87

Other than making a Dewar Jar, the Dewar seal may be applied to making either end of a gas discharge tube where you wish to have the lead-in wire protected. (See Figure #88.)

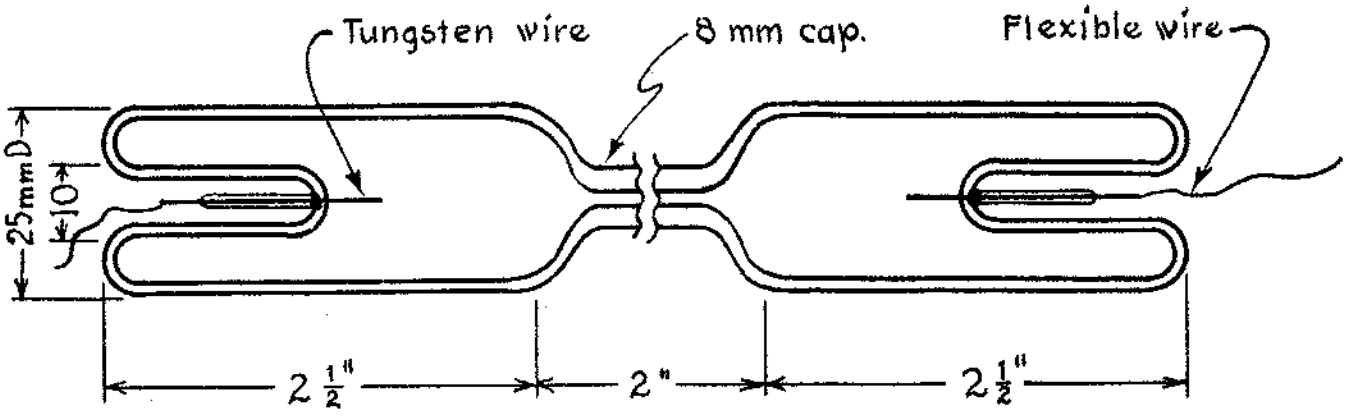


Figure 88

A Dewar seal made with a standard taper ground joint may be used as the top of a distillation column. (See Figure #89.)

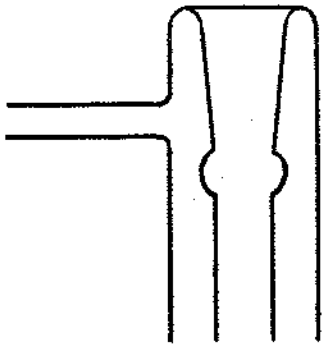


Figure 89

Lesson 20

GLASS TO METAL SEALS -- ELECTRODES

There are many kinds of metals to which glass will seal. The most common are: Tungsten, Copper, Kovar, Platinum. In this fundamental course in scientific glassblowing we deal only with Tungsten. There are five steps in making a Tungsten-to-glass seal. Before starting to make this seal, clean your bench of all pieces of small diameter tubing. You will be working with two different kinds of glass and it is important not to mix them up.

In your set you will find two pieces of Tungsten wire and four pieces of glass tubing marked Nonex. This glass differs from Pyrex in that its expansion coefficient is greater. Yet Nonex has almost the same expansion and contraction characteristics as Tungsten. Thus, it will seal readily to Tungsten and even though having different characteristics, will still seal to Pyrex.

1. Choose a piece of 10 mm. Pyrex tubing from your set and put your blow hose on one end. Lay this aside for a moment. Now cut a short piece of Nonex tubing and stopper one end. Next, seal the two pieces of tubing together by using a very sharp fire with an abundance of oxygen. If you have a soft or bushy fire the lead in the Nonex is reduced out and your seal will be black in color. If done properly, the Pyrex-to-Nonex seal should be clear.

   Once you have the two tubes sealed together, pull the Nonex end off into a round bottom, leaving about 1/2" of Nonex on the end of the Pyrex. Now blow a 5 mm. hole in the end. For clarity the Nonex is shaded dark in the drawing, but of course is actually the same thickness as the Pyrex. (See Figure #90.)

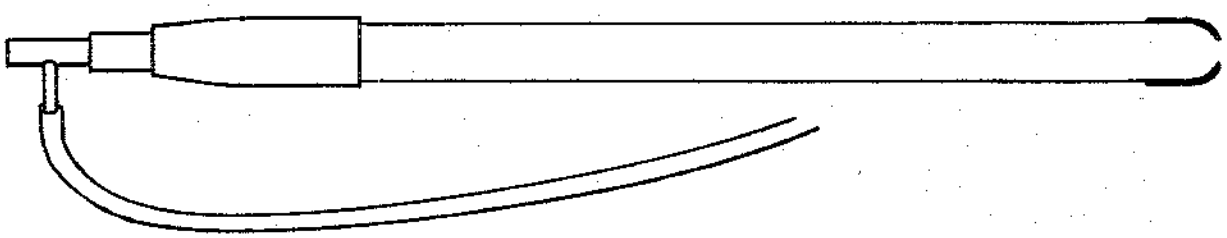


Figure 90

Put this piece aside for a few moments and cut a piece of Tungsten wire about 1-1/2" long. Tungsten is an extremely tough metal and can best be cut on an emery wheel. Do not use wire cutters (diagonals) -- it will destroy their cutting edges. Hold this short piece of wire with a pair of pliers and heat one end red-hot. Also heat the end of a piece of Pyrex rod and touch the two hot ends together. Heat until the wire sticks to the glass rod. The reason for this is that it enables you to have a handle with which to rotate the wire. (See Figure #91.)

Figure 91

3. Ordinarily Tungsten wire is dirty and black in color. Note that the wire supplied in your set is shiny -- since it is clean, annealed wire. If your wire were dirty and black with oxide, it would be necessary to clean it before sealing it to the glass. This is done by heating the wire red-hot in your fire, then passing it quickly through a piece of sodium nitrate. The wire immediately becomes bright and shiny -- the same as the wire supplied in your set.

However, it is necessary that your clean wire be reoxidized with a very thin coating of oxide before it can be sealed to the glass. The reason for this is that glass actually seals to a very thin coating of oxide and not to the metal itself. Glass will not seal well to a thick coating of oxide because of the difference in thermal expansion between the two substances.

To reoxidize your clean annealed wire, pass it quickly through a sharp flame. Note that the wire turns blue-black. This indicates about the right amount of oxide coating. If the color is dark black, the oxide coating is probably too heavy. If this happens, reclean and reoxidize. When the wire is coated, lay it aside for a few moments.

4. Now take up the Nonex tubing you pulled off to make the round Nonex end in Step No. 1 and heat in the center with a sharp flame. When soft, pull it apart and you will note that the area that was soft is now a very fine tube. (See Figure #92.)

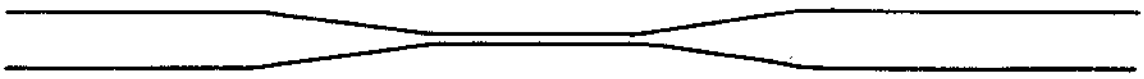


Figure 92

Cut out a section of the fine tube that is about 5/8" long and just large enough to slide over your tungsten wire. Be sure to choose a section that makes a nice close fit. Put this little piece of tube aside with your tungsten wire. (See Figure #93.)

Figure 93

Now take one of your small pieces of Nonex glass and heat one end until it thickens and completely closes. Touch to this thick blob of glass a short section of Pyrex rod and slowly pull apart. You will note that you are actually making a solid rod of Nonex. Pull out about 2" of this Nonex rod. (See Figure #94.)

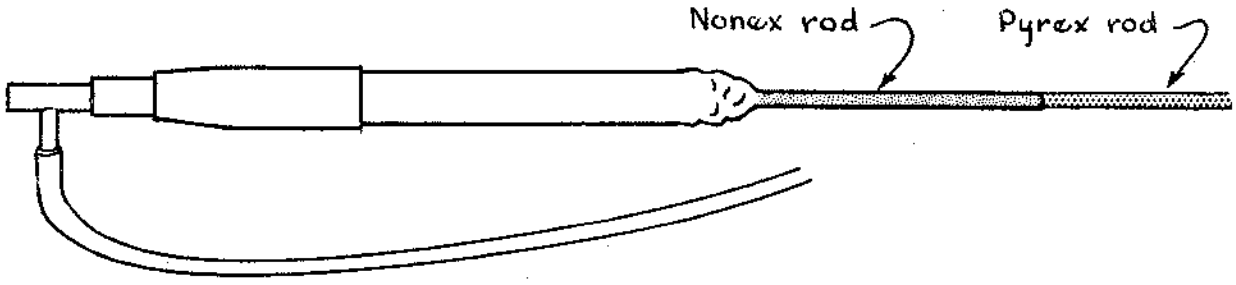


Figure 94

Put this short section of Nonex rod aside for a moment.

5. Adjust your fire so that it is small and sharp. Hold in your left hand the Tungsten wire and the small Nonex tube that envelopes it. Position it so that there is an equal amount of wire showing from either end. Rotate slowly in the sharp fire starting from the end closest to you. Allow the glass to shrink down and seal to the oxide on the metal. If the coating of oxide is the right thickness and you do not entrap any air bubbles, your seal should be a reddish brown color. (See Figure #95.)

Figure 95

Now, still holding the wire in the left hand, change its position so that the glass sleeve is held downward and to the side of your fire. (See Figure #96.)

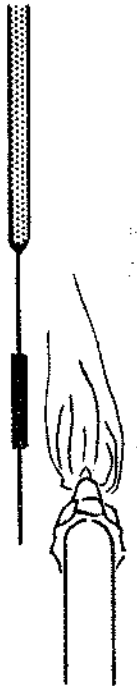


Figure 96

Hold the small section of Nonex rod in your right hand, heat both the upper end of the sleeve and the Nonex rod. (See Figure #97.)

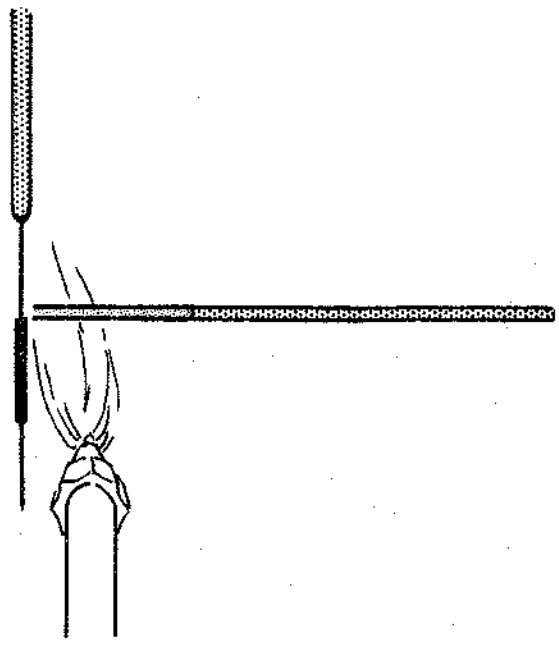


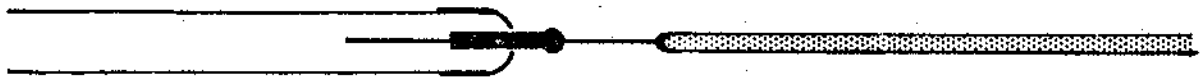
Figure 97

Let a small blob of glass form at that point and remove Nonex rod. (See Figure #98.)

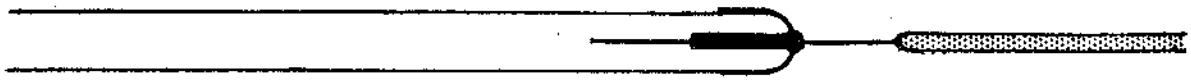
Figure 98

Now heat this blob of Nonex glass until it softens and smooths out into a perfect sphere.

6. By this time you should have learned good coordination in your rotating, which is now very necessary in this final step or you may spoil all your work up to this point. Take your original length of 10 mm. Pyrex with the short section of Nonex sealed to it and put your blow hose on the Pyrex end. You may use your V support here if you find it more comfortable. Hold your work in your left hand and with the right hand insert the Tungsten wire so the little round Nonex bead fits up to and touches the edges of the small hole in the Nonex tubing. (See Figure #99.)



A.



B.

Figure 99

Rotate and heat in a sharp fire, making sure the fire is pointed at the Nonex bead. As the bead gets soft, push gently until it fuses with the edges of the larger Nonex tubing. Continue heating until completely fused together. Blow just enough to keep the larger tube from collapsing down around the little glass sleeve on the inside. Here your coordination must be perfect. The right hand cannot move from side to side or the wire will stick to some part of the larger tube. Your finished seal should look like Figure #100.

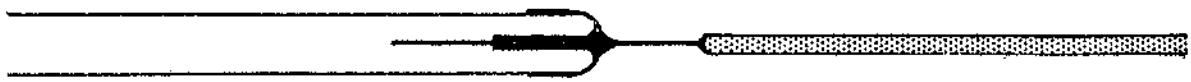


Figure 100

The five steps are listed below for your review:

#1. Seal Nonex end to Pyrex tubing.

#2. Clean wire.

#3. Pull small Nonex tube or sleeve.
Pull small Nonex rod.

#4. Seal sleeve on wire.
Put bead on end of sleeve.

#5. Seal beaded wire in large tube.

Tungsten to glass seals are mainly used for electrical connections where you wish to pass an electrical current through a piece of wire from the outside of a glass tube to the inside. But they also have other applications such as a hook to suspend a small basket on the inside of a larger tube for evaporation purposes. Also they can be used as support rods. Larger Tungsten rods sealed into a flask have been used as bearings where other pieces of metal must move up and down the length of a given tube. The most common use, however, is the electrical connection.

Lesson 21

GENERAL REVIEW

Practice in the early stages is of utmost importance if the student expects to get the most out of this course. The ability to rotate properly and to make a smooth butt seal are the two keystones upon which scientific glassblowing rests. If you can't make a good butt seal, you will never be able to make a good ring seal. If you can't make a good T-seal, you will never be able to make a passable condenser or cold trap.

The equipment supplied in your set is fundamental. A professional glassblower's laboratory is usually supplied with many more burners, both larger and smaller, glassblowing lathes for working large tubing, multiple tip cross fires for bench work in the larger diameters, cut off saws, spot welders, annealing ovens, baking out ovens, pumping and vacuum equipment.

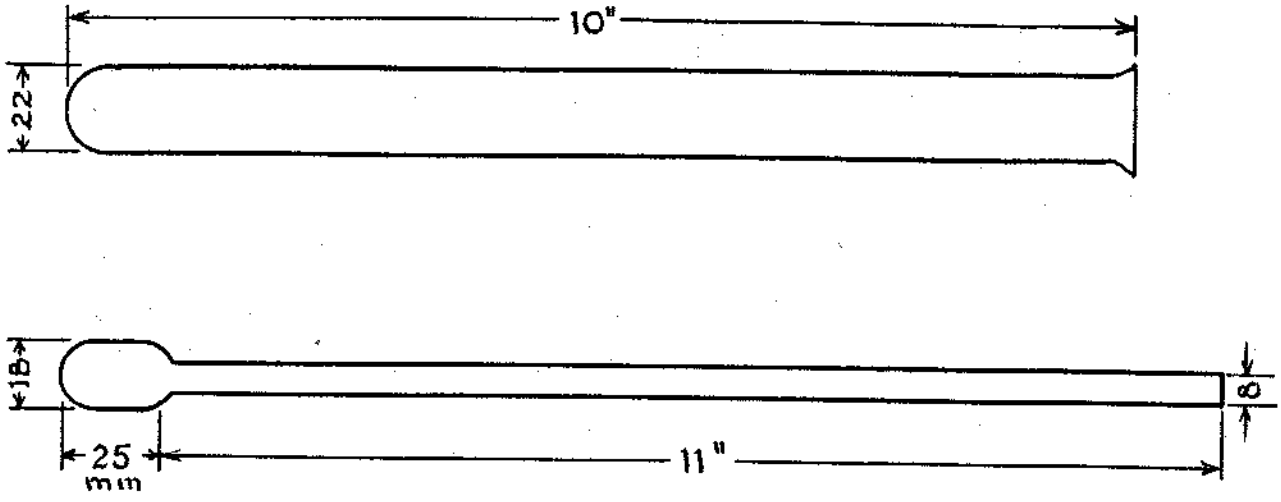
But regardless of the abundance of mechanical equipment, a good glassblower does much of his work by hand on his bench.

Needless to say, anyone going into scientific glassblowing as a profession will be helped by having a background in the field of chemistry or physics or both.

A high school or college student completing this course should be able to carry out many glassblowing jobs that otherwise would have to be sent out to a professional glassblower. A student who actually masters this course is well on his way toward becoming a first-rate professional glassblower.

After completing this course you should be able to make many pieces of apparatus by following a simple drawing. As a general review, drawings for new types of apparatus you haven't made yet are given on the next few pages. You have already been shown how to make the basic parts of these types of apparatus. Now you will be given a drawing and a few hints, but the rest is up to you.

1. Homogenizer



Note: Outer diameters given in millimeters.

Figure 101

After making the tube and the pestle, grind the latter into the large tube with a coarse grinding compound. The walls of the tube and the base of the pestle will lose their smoothness and become rough. The primary use of a homogenizer is to grind animal tissue in biological and zoological laboratories.

2. Connecting Bulb

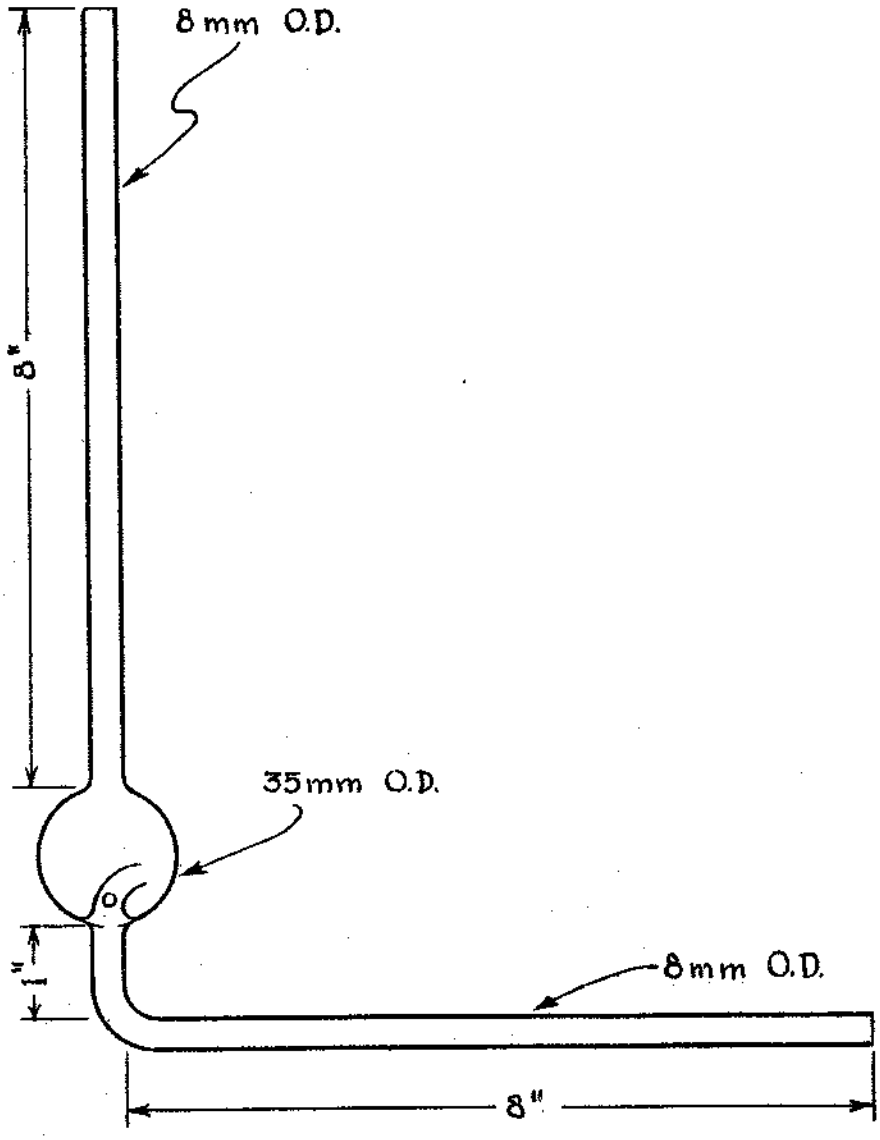


Figure 102

Be sure to blow small hole in inner tube. This will allow liquid return. This trap is generally used between mechanical vacuum pump and glass system to keep oil from surging up into system in case of breakage.

3. Cold Finger

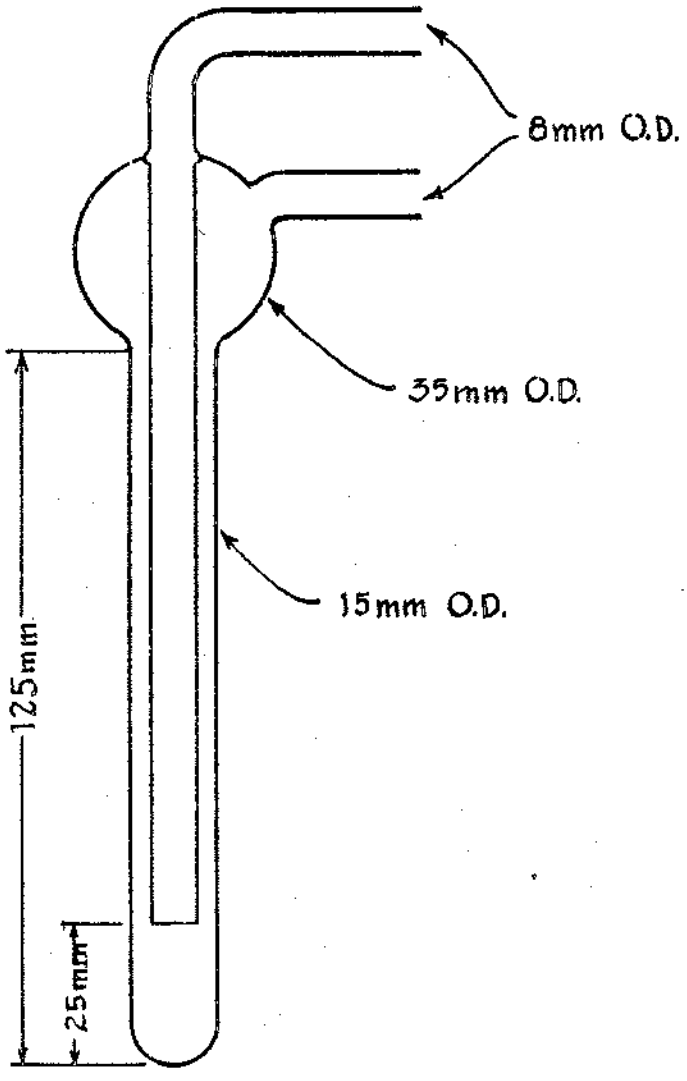


Figure 103

A cold finger is the same thing as the cold trap you made in Lesson 15. The cold finger, however, is shaped differently. It is used in a vacuum system to trap out condensable vapors. A Dewar jar with some coolant such as liquid nitrogen or dry ice and acetone should be placed up over the body of the cold finger. Blow bulb on end of 15 mm. tube first. Inner tube may be wrapped with asbestos, then taken out later.

4. Vacuum Trap (cylindrical shape)

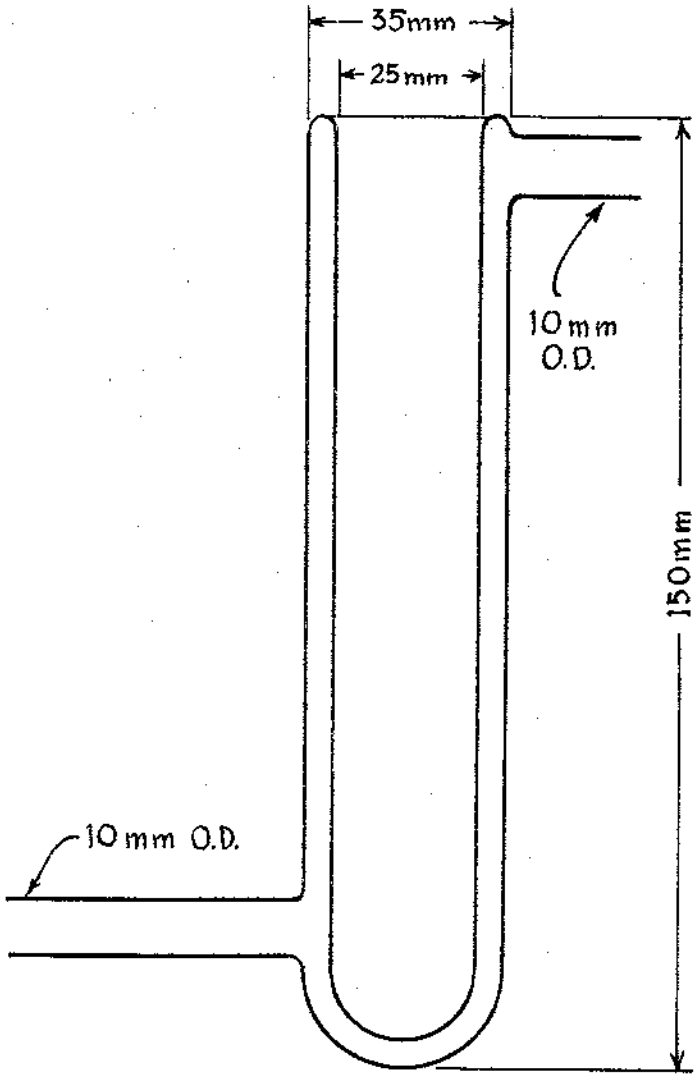


Figure 104

This is a form of Dewar jar but it is not used as Dewar jars are generally used. Instead of a cold trap or cold finger down inside, this Dewar jar is an integral part of a vacuum system. The coolant is poured down in the inner cup and the vapors are pumped around the coolant (dry ice and alcohol or liquid nitrogen).

Hint: After Dewar seal is made bend top inlet up and shape it into a handle. This allows you to round out the bottom of the Dewar jar by rotating in the flame.

5. Distilling Bulb (plain type)

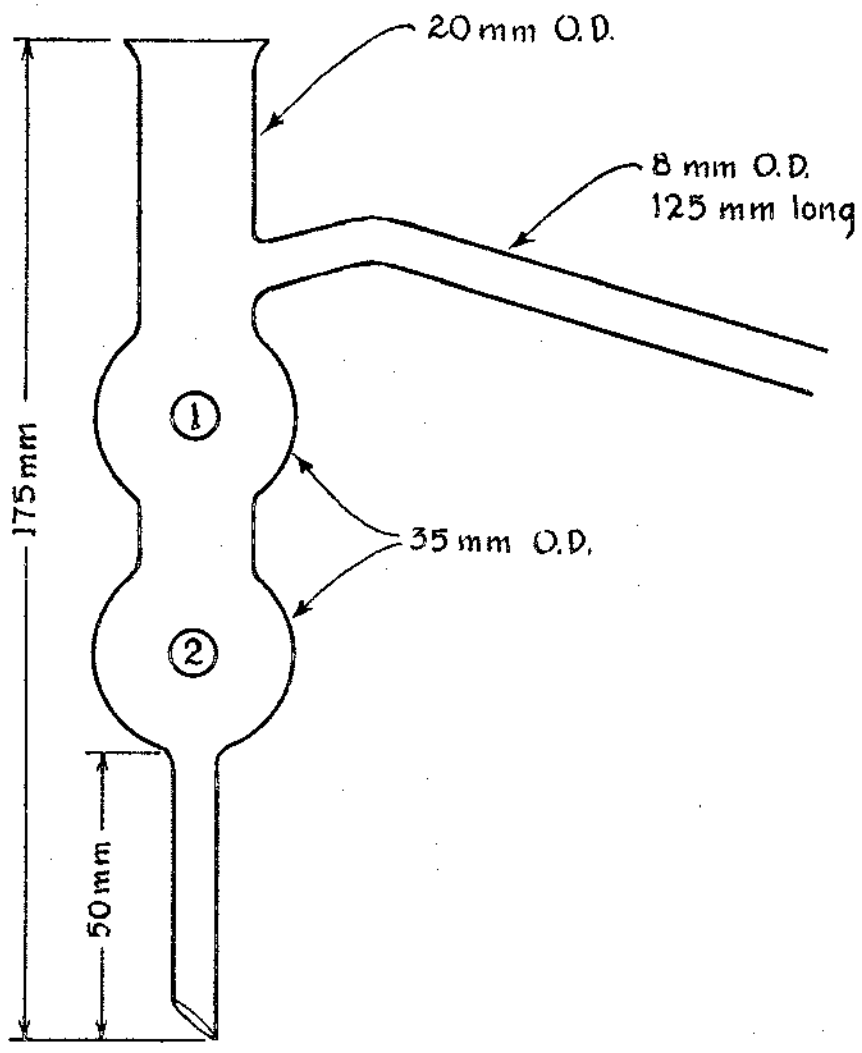


Figure 105

Hint: Blow bulbs from long length of 20 mm. tube. Blow No. 1 bulb first, No. 2 second. Following this method you will have less weight to carry in the right hand.

6. Distilling Apparatus

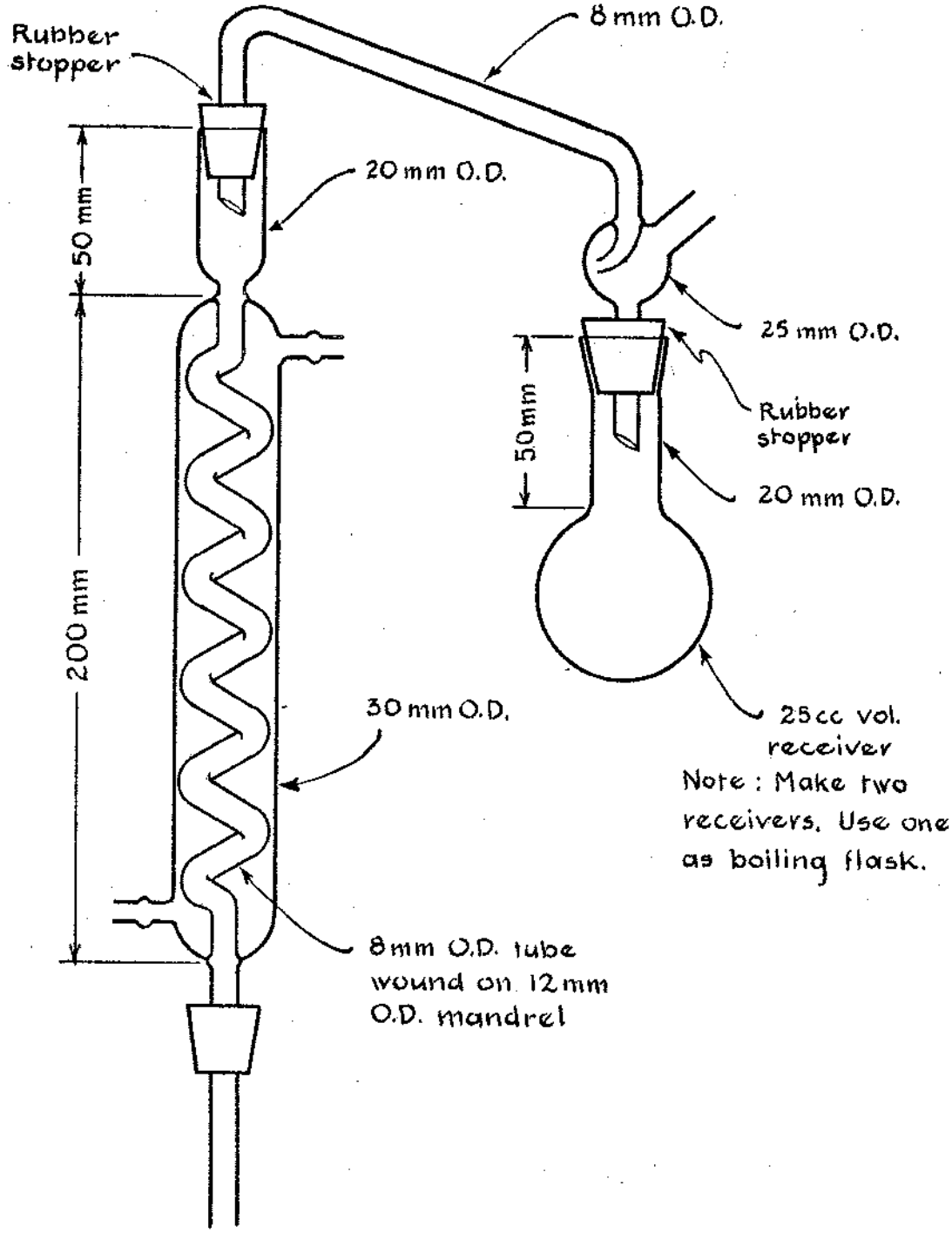


Figure 106

Hint: Hold coil in large tube with long strips of asbestos tape. After first ring seal and side tube are made, pull out asbestos strips. Do not wet (as in Lesson 19). Be sure, however, to wet glass tubes before inserting them into 1/4" holes drilled in rubber stoppers. Water will lubricate the glass for easy insertion.